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## The Month.

**H.M.S. *Montagu*.**—It is much to be regretted that owing to unpropitious weather it was impossible to complete preparations for raising H.M.S. *Montagu* during the high tides of August 5th. The only favourable time of the year for salvage operations has now gone by and the hull of this fine vessel is consequently doomed. This unfortunate result must not be attributed to any lack of energy on the part of the authorities, for, as the following brief notes will demonstrate, everything possible was done to save the ship. Preliminary examination by divers showed that a large rock had penetrated about 10 ft. into the ship under the forward capstan engine, and that several other large holes had been made. The starboard bilge keel was almost entirely carried away, the port propeller bracket and shaft had disappeared, the starboard propeller and bracket were damaged, and the lower parts of the sternpost and rudder were broken off. Any attempt to repair the bottom of the ship would have involved blasting away the rocks, and if the large amount of work necessary had been accomplished it might have been of no avail owing to the probability of further damage in floating the vessel off. Consequently it was decided to clear the ends of the ship as far as possible by pumping out the watertight compartments, to use compressed air in the engine and boiler rooms and in the forward capstan engine room, and to secure large tanks, or camels, to the bow after taking off as much armour as was practicable. While preparations of this kind were in progress, the ship was lightened by the removal of guns, torpedo nets, chain cables, boilers, and parts of the machinery. On June 10th,

ten days after the vessel struck, nine centrifugal pumps, from 3 in. to 12 in., were in operation, and a 12 in. pump was also available on one of the salvage ships. Shortly afterwards seven other pumps were in position providing a total pumping capacity of nearly 311,000 cub. ft. per hour, not far short of 2,000,000 gallons per hour. By means of these pumps the water was cleared down to about 2 ft. above the platform deck, as the dimensions of the suction boxes would not permit water to be reduced to a lower level. Therefore suction wells were fixed after much difficulty in the forward torpedo room and other spaces. An attempt to make the lower deck watertight round and inside the revolving ammunition trunk was only partially successful owing to the fact that the trunk had been forced up about 6 in. and moved slightly with every movement of the ship. A 12 in. pump was tried in each of the boiler rooms with little effect, and attempts to clear the lower coal bunkers from water were equally futile as most of them were nearly full of coal. To prevent the ship from bumping it was necessary to let her fill at high tide, and to arrange for pumping out the various compartments with great rapidity between tides. Arrangements were also made for flooding the compartments for the purpose of correcting any heel that might occur in floating the ship. By June 15th a staff of shipwrights sent from Pembroke Dockyard had closed in the hatches to the engine and boiler rooms at the level of the main deck, and on the same day three oil-driven air compressors were set to work, these engines having a collective capacity of 310 cub. ft. of free air per minute. At high tide the water level was lowered by 11 ft. but numerous leaks were detected. A further trial was made four days later with compressors having the total capacity of 755 cub. ft. per minute. As a result it was estimated that to float the ship plant would be required capable of dealing with 6,000 cub. ft. of free air per minute. After the requisite plant had been delivered and erected, a complete trial was made on July 13th, and it was then found that additional boiler power must be added. By July 20th, the total weight of 140 tons of armour had been removed, and twenty air tanks, with a buoyancy of 600 tons, were fixed to the ship's sides by July 21st, and by blasting, whenever the swell would permit, the rocks on the port bow were considerably reduced in height. After the last mentioned date the weather became so unfavourable that very little progress could be made, and the hull became so strained by heavy seas as to render it doubtful whether it would be worth salving. On July 22nd and 23rd a trial of the floating plant was made, and if the conditions had been favourable an attempt would probably have been made to float the ship. As things turned out there was a heavy swell and the vessel began to bump so much that it was decided to stop the trial before serious damage resulted. Then additional air tanks were fitted, more armour plates removed, and more air leaks stopped. On July 26th, owing to a long ground swell, the ship bumped very much and was carried about 13 ft. inshore forward and a similar distance outwards aft. The straining did serious injury to the hull, but in spite of this salvage work was pushed forward in the hope that the ship might be floated on August 5th. Unfortunately, the swell again increased, and on August 1st the sea was so rough that all work had to be suspended and the salvage ships had to seek shelter. On August 4th the weather was still unfavourable, and as preparations for utilising the high tide could not be completed, the decision was reluctantly made to suspend operations. In view of the damage done and the approach of autumn it can scarcely be doubted that this was the only course open. We have only been able to mention the bare outlines of the important work done in the hope of saving the *Montagu*. The promptitude and energy displayed by the naval authorities and by the Liverpool Salvage Association, whose assistance was engaged, deserve the fullest appreciation, and their efforts would probably have been crowned with success if uncontrollable forces had been more favourable.

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**Coal Gas and Air.**—In view of the uncertainty prevailing with regard to the laws governing the action taking place during the explosion of mixtures of coal gas and air, the recent investigation of Dr. F. Haüsser, of Kaiserslantern, is of considerable interest. The conditions in Dr. Haüsser's research, such as the proportions of the gas and air mixtures, the initial and final pressures, the method of ignition, and the arrangements generally, were very much the same as those encountered in internal combustion engines. Ignition was effected by means of an electrically-heated platinum wire in a cylindrical steel vessel, pressure being measured by the aid of a "Rosenkrauz" indicator, the drum of which was operated at 1,400 revolutions per minute by

a small electric motor. As the gas was stored over water it was saturated with water vapour in all the experiments. The ignition pressures in the five series of tests were 14·4, 24·18, 39·8, 50·5, and 62·6 lb. per square inch absolute. The proportion of gas in the explosive mixtures varied from 6 per cent. to 20 per cent. Dr. Haüsser chiefly desired to determine the maximum pressures, and the most interesting curves obtained are those showing the maximum pressures produced by exploding mixtures with increasing percentages of gas, and the duration of the explosion periods. The maximum pressures attained in the first four series of experiments were 85·3, 185, 312·9, and 384 lb. per square inch. In the fifth series the pressure could not be measured, being beyond the capacity of the indicator. It may be pointed out here that the maximum pressure was invariably recorded for mixtures containing about 16 per cent. or 17 per cent. of gas. Dr. Haüsser defines the period of explosion as that intervening between the moment of ignition and that of maximum pressure. This period decreased with the increased percentage of gas in the mixtures as shown in the subjoined table. It will be observed that the combustion periods are of longer duration than those given by tests of internal-combustion motors, probably owing to incomplete combustion in the latter. Thus the adoption of rich mixtures is suggested as desirable, of course, when consistent with safety. For computing the specific heat of the gases, the temperatures, the composition of the mixture and of the products of combustion, the density and calorific value of the gas and the heat losses were carefully determined. Dr. Haüsser based his calculations of Mallard and Le Chatelier, making due allowance for the dissociation of water vapour and carbon dioxide. He showed that the dissociation of the former may have considerable influence, particularly at temperatures over 2,000° C. absolute, but concluded that the dissociation of carbon dioxide is not of importance. He studied the oxidation of nitrogen in a special vessel about double the size of that employed for his main investigation, and in this way obtained results generally confirming the explosive pressures ascertained in the five series of experiments. In calculating the mean specific heat of the gases, Dr. Haüsser rejected the results given by the experiments in Group I., where the mixtures contained less than 11 per cent. of gas. The table printed on this page, contains some of the more important results. It will be seen that the mean specific heat are greater than those determined by Mallard and Le Chatelier, and it is probable that the values found by those investigators are too small. The decrease of specific heat with increase of pressure is possibly due to dissociation, and therefore the mean specific heat may be regarded as being affected in opposite directions by pressure and temperature. Dr. Haüsser concludes that when the gases are at low temperatures any addition of heat energy is spent in overcoming molecular attraction rather than the union between atoms. On the other hand, at high temperatures, he suggests that any addition of heat would tend to dissociate the molecules into atoms. Thus, in one case, the increase of pressure would increase the specific heat owing to increased density, and in the other it would diminish the specific heat by diminishing dissociation.

| Group No. | Initial Pressure (absolute). | Initial Temperature (absolute). | Gas in Mixture. | Maximum Pressure. | Final Temperature (absolute). | Explosion Period. | Heat Loss during Explosion. | Mean Specific Heat. |
|---|---|---|---|---|---|---|---|---|
| | lb. per sq. in. | deg. C. | per cent. | lb. per sq. in. | deg. C. | Second. | per cent. | — |
| II. | 27·024 | 291 | 11 | 125·16 | 1,390 | 0·103 | 8·9 | 0·403 |
| | — | — | 12 | 135·83 | 1,515 | 0·070 | 6·2 | 0·408 |
| | — | — | 13 | 145·79 | 1,630 | 0·050 | 4·4 | 0·414 |
| | — | — | 14 | 154·68 | 1,785 | 0·037 | 3·3 | 0·423 |
| | — | — | 15 | 161·79 | 1,825 | 0·030 | 2·6 | 0·432 |
| III. | 39·8 | 292 | 11 | 206·23 | 1,560 | 0·095 | 6·4 | 0·357 |
| | — | — | 12 | 225·00 | 1,700 | 0·065 | 4·5 | 0·362 |
| | — | — | 13 | 241·79 | 1,840 | 0·045 | 3·1 | 0·366 |
| | — | — | 14 | 254·24 | 1,940 | 0·037 | 2·5 | 0·373 |
| | — | — | 15 | 264·91 | 2,020 | 0·031 | 2·1 | 0·384 |
| IV. | 50·49 | 294 | 11 | 268·4 | 1,620 | 0·095 | 5·3 | 0·346 |
| | — | — | 12 | 293·3 | 1,770 | 0·062 | 3·4 | 0·350 |
| | — | — | 13 | 314·7 | 1,900 | 0·045 | 2·6 | 0·353 |
| | — | — | 14 | 336·0 | 2,030 | 0·033 | 1·9 | 0·356 |
| | — | — | 15 | 353·8 | 2,140 | 0·026 | 1·5 | 0·363 |
| V. | 62·58 | 292 | 11 | 336·0 | 1,620 | 0·105 | 4·7 | 0·340 |
| | — | — | 12 | 359·1 | 1,760 | 0·080 | 3·7 | 0·343 |

**British and American Railway Cars.**—To American engineers who are accustomed to the massive proportions of Pullman cars, British passenger rolling-stock appears to be of astonishingly frail construction. It never has been the practice in this country to design passenger cars for withstanding the effects of collision, and the small number of accidents has probably a good deal to do with the comparative weakness of such vehicles. Nevertheless, British railways are by no means free from mishaps which, as we know from recent experience, are not infrequently attended by serious consequences. Carriages are crumpled up,

pinning helpless passengers between the seats; the woodwork is wrecked, inflicting fearful injuries; and the outbreak of fire almost invariably adds further terror to a collision or derailment. It is all very well for railway engineers to profess the view that accidents are too few and far apart to justify the additional expense of building stronger and more fire-resisting vehicles, but we are certain that the public hold the contrary opinion, and in this they are undoubtedly right. The strength and safety of the American Pullman is proverbial, and it is capable of passing through ordeals quite as severe as those of Witham, Salisbury, and Saltcoats with very little injury. In fact, cases have been known of American cars which after having been derailed have rolled down steep embankments without suffering material injury. The inferior character of permanent way construction, the general inefficiency of signalling systems, and the hap-hazard methods of operation characterising railways in America, have been largely responsible for the great strength and weight of passenger cars in that country. There collisions and other mishaps are looked upon as inevitable, and the attempt is made to safeguard passengers by means of the cars. Here accidents are regarded as remote contingencies, and the safety of the public depends upon the line and careful operation. On the whole, the British system is infinitely preferable to that prevailing on the other side of the Atlantic, but our passenger cars are really quite inadequate for modern requirements. Without approaching the proportions of the over-heavy American Pullman, our carriage frames ought to be stronger, timber bodies must be replaced by steel, and the use of non-flammable materials should be made compulsory.

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**The Trades Disputes Bill.**—With party politics THE ENGINEERING REVIEW has no concern, but we cannot pass in silence so unfair and so glaring a piece of class legislation as the Trades Disputes Bill. It is truly wonderful that an assembly of honourable men should be capable of accepting the proposition that a trade union shall be allowed to commit "any tortious act" with utter impunity. If accepted by the House of Lords as it stands, the measure will authorise trades unions to do wrong without punishment. A tortious act covers slander, libel, and conspiracy, as well as other offences that may be committed against the public as represented by employers. If passed into law the bill will permit the funds of trades unions to be expended in nefarious ways for the injury of employers, who in turn will have no claim for damages against the union funds. For the first time in English history the principle has been enunciated by the House of Commons that wrong may be done without permitting the wronged person any legal redress. It is humiliating to think that political partisanship can cause otherwise sensible and honourable men to accede to so iniquitous a doctrine, and we sincerely hope that the House of Lords will reject the Trades Disputes Bill, not merely because it is unfair to employers of labour, but for the stronger reason that if passed in its present form Great Britain will stand before the world as a maker of unjust laws, and a country where evil-doers are under the direct patronage of the State.

# The Dimensions, Proportions, and Forms of Ships.

*By H. BEAUMONT DONALDSON.*

WHEN discussing any special branch of naval architecture, particularly such a one as my subject, it is difficult—in fact, well-nigh impossible—to confine one's attention rigidly to the topic under consideration, so many are the side issues. Each particular class possesses features distinctive to itself which the naval architect must perforce consider to ensure a satisfactory design.

For example, ships may be classed under three distinct headings: War vessels, whose sole duty it is to safeguard the interests of the empire throughout the globe; passenger vessels for the safe and speedy conveyance of travellers from one country to another; and cargo steamers, for the purpose of effecting an interchange of the products of various countries.

Perhaps of the three, warships call forth the greatest amount of ingenuity on the part of the designer. Being in reality a floating battery, armament is naturally of the primary consideration. To provide a reasonable amount of protection over the vitals, efficient protection must be devised, either in the shape of thick protected decks, as in many of our fast cruisers, or a combination of side armour, and protective plating on a deck or decks.

This involves at the outset a very large expenditure of weight on armour and armament. Quick steaming and large radius of action—most important characteristics—provide other items to which must be allotted a large share of weight, and introduce the question of dimensions and form consistent with an economical expenditure of fuel, whilst the most important feature of all, sufficient stability, introduces a requirement to which all the foregoing must, if necessary, be subservient.

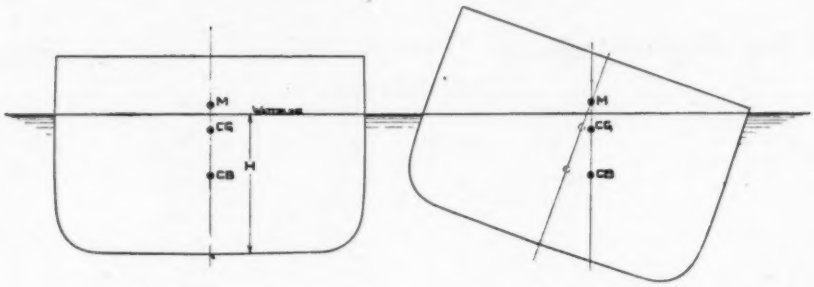
When designing any new type of vessel, it is frequently found that all these requirements are diametrically opposed one to another, so that the finished result presents a vessel in which all conflicting elements are, as far as possible, eliminated, and which possesses the maximum amount of armament, armour, speed, coal supply and safety it is possible to give under the existing conditions.

The distribution of guns at a more or less great height above the load waterline, a large amount of armour, also with its common centre of gravity at a considerable distance from the bottom of the keel, associated with the displacement to carry all the weights involved and the fine form inseparable from the high rate of speed, find as a natural sequence a large proportion of beam in terms of length.

Outside requirements will further call for consideration. The draught must be limited by the depth of water at the various harbours the vessel will visit, and as docking is of a more or less frequent occurrence, the breadth must not exceed that of dock entrances.

To grasp the effect of different proportions of dimensions one to another and on the safety of the ship, a brief consideration of the fundamental principles of stability is necessary.

Let L = length.
B = breadth.
H = draught.
$\Delta$ = displacement.
Cf = co-efficient of fineness.
I = moment of inertia of water-line.
C B = centre of buoyancy.
C G = centre of gravity of ship.
M = Transverse metacentre.




In upright condition. In inclined condition.

FIG. 1.—DIAGRAMS SHOWING POSITIONS OF CENTRES.

The metacentre is an imaginary point in the centre line of a ship in the upright condition produced by the intersection of a line drawn vertical to the new waterline of the ship at any angle of keel, through the new position of the centre of buoyancy, and fixes a limit above which the centre of gravity of the ship must not pass under conditions of stable equilibrium.

The distance B M, between C B and M (see diagram I), is determined by the displacement and the area of the waterline, and is arrived at by the formula $B\,M = \frac{I}{\Delta \text{ in cub. ft.}}$. Now I = sum of waterline breadths, cubed, multiplied by the distance apart of the stations at which the breadths are measured; so that the full formula may be written $B\,M = \frac{2}{3}\int \frac{\left(\frac{B}{2}\right)^3 dx}{\Delta \text{ in cub. ft.}}$, or put into a more general and approximate form $B\,M = \frac{K \times L \times B^3}{\Delta \text{ in cub. ft.}}$, K being a co-efficient depending upon form of the waterline. Simplifying this equation it becomes $Y\frac{B^2}{H}$, the co-efficient Y being the quotient of K and Cf.

From the note on the distribution of weights it will be readily deduced that the common centre of gravity of the ship will be at a considerable proportion of the depth from the keel. In order that the metacentre must not fall below this position, the dimensions and form must be such as to ensure an adequate height.

Reverting to the formula $B\,M = \frac{K \times L \times B^3}{\Delta}$ it will be seen that B enters the equation in the third power. Therefore any increase in the breadth will have a proportionately greater effect on the stability than a change in any other dimension; added to this the fine form of immersed body and waterline to comply with the requirements of speed, it is obvious that the breadth will diminish rapidly before and abaft the widest section, hence a considerable amount of breadth is of paramount importance in the first instance to ensure satisfactory stability (see diagram 2, curve A).

The question of freeboard is not one that requires the careful amount of manipulation associated with the design of cargo carrying steamers, as the inherent requirements of a war vessel provide a much greater amount than would be assigned under Board of Trade regulations.

The naval designer has one great advantage over his colleague in the merchant service, inasmuch that all the heavy weights, which go to make up the displacement, are fixed, and he is consequently in a position to produce a vessel whose seagoing qualities can be estimated before even she is put in commission.

The centres of gravity of armament, armour, hull, machinery outfit, etc., can be estimated with great accuracy by detailed calculation, or arrived at approximately by reference to tabulated data of somewhat similar ships already built, whilst the position of the metacentre is, of course, arrived at by direct calculation.

The effect of the consumable stores, such as ammunition, bunker coal, fresh water, provisions, &c., can be easily arrived at; hence all the conditions under which the ship is likely to sail may be predicted, and provision made against any contingencies that may arise during service.

The old fallacy that large beam and great immersed midship area in themselves were derogatory to speed has been dispelled for all time by the exhaustive experiments commenced by the late Mr. Froude, and carried on later by his son at the Government experimental tanks at Torquay, and it is largely to the invaluable researches of these gentlemen that we owe the present state of our knowledge.

An illustration of the differences of waterlines may be seen by reference to diagram 2. For convenience of comparison all the types chosen have been standardized on a length of four hundred feet.

Curve A shows the load waterline of a modern first-class line of battleship. Here it will be noted that there is absolutely no parallel middle body, which forms so prominent a feature in almost all classes of merchant boats, the entrance and run being made as free as possible consistent with the required stability and displacement.

Curve B represents the load waterline of a modern 22 or 23 knot armoured cruiser. This class of vessel is gradually assimilating the features of a first-class line of battleship; the absence of a primary armament of heavy 12 in breech-loading guns prevents it being placed in the same category as regards weapon of offence, but the additional four or five knots gives it a great advantage as a mobile unit in naval warfare.

Curve D introduces a type of form common to high-class Atlantic liners while curve "C" shows a typical instance of the load waterline of a modern tramp steamer; the bluff ends and great length of parallel middle body supply the inertia lost by a proportionately diminished beam, and while this form is admirably suited within certain limits to the work required, it will be seen that its application to a high-speed vessel would result in a disastrous failure, the differences in speeds, involving widely different wave resistances, &c., being so great.

Turning from the consideration of warships to that of merchant vessels, the conditions at once become widely different.

In the place of a number of items of great weight, distributed at known positions throughout the ship, we have to deal with a floating body in which the initial weights and centres to consider are hull and machinery, the sum total resulting in a displacement very much

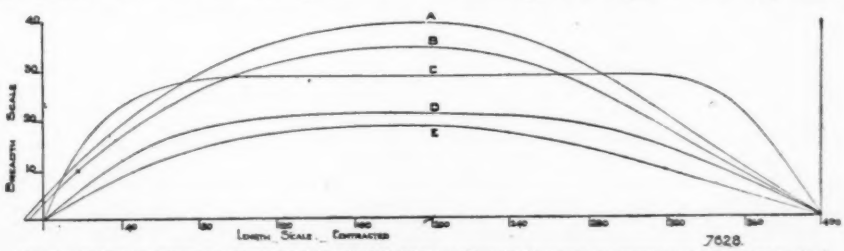



FIG. 2.—DIAGRAMS SHOWING TYPES OF LOAD WATERLINES OF VARIOUS CLASSES OF VESSELS STANDARDIZED ON A LENGTH OF 400 FT.

A. First-class line of battleship. B. First-class cruiser. C. Cargo steamer.
D. High speed Atlantic liner. E. 30-knot torpedo boat destroyer.

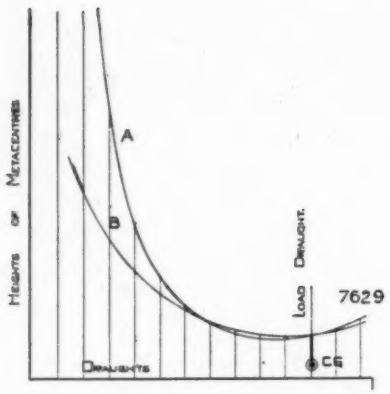



FIG. 3.—DIAGRAM SHOWING TYPICAL METACENTRICAL CURVES FOR—

A. Modern cargo steamer.
B. High speed passenger vessel.

lighter than the displacement when floating at the assigned load draught, the greater the difference the greater the satisfaction of the owner.

In the case of passenger vessels this does not apply to any great extent as in first-class boats, or at any rate only a very small amount of capacity is available for carrying cargo. The high rate of speed means that an enormous amount of coal consumption is necessary in order that it may be attained. Here again the variations in draught are not so great, for the permanent weights—hull, machinery and outfit—comprise so great a proportion of the total displacement that the naval architect is able to predict, with a considerable degree of certainty, the changes in metacentric height likely to occur, and can consequently determine on such high dimensions and proportions as to satisfy any alterations which may arise to disturb the position of the centre of gravity, and while the position of the metacentre will in most cases fall from the locus it occupies in load condition, yet it is of so small an amount as to be hardly appreciable; indeed it is most probable that by the time the bunker coal and stores are about exhausted the metacentre will be on the upward grade again. The character of the metacentric curve for a vessel of the fast liner type is illustrated on diagram 3. The reason for the great increases in height at lighter draughts is that the displacements decrease at a much more rapid rate than the moments of inertia of the respective waterlines.

In cargo boats steaming at only ten or eleven knots per hour, the horsepower required amounts to a very modest figure, so that the coal consumption, and consequently space and weight allotted to bunkers and machinery, drops accordingly. The weight of the outfit, covering such items as accommodation, boats, and the hundred-and-one fittings which go to make up a well-equipped passenger vessel, are cut down to a minimum, leaving a very large balance of displacement between actual light weight of ship—or light displacement—and the load displacement which is utilized to carry cargo, and is termed "deadweight."

In a case of this kind it is practically impossible to foretell the positions the centres of gravity may occupy during the voyages, as it depends entirely on the nature of the cargo carried and the manner in which it is stowed. Incidentally it may be mentioned in this respect, that a great amount of laxity is commonly displayed in loading vessels; the stevedore—when a general cargo is carried—does not pay any regard to, in fact, probably does not know as to how the disposition of weights may affect the sea-kindliness, but packs everything away as though it was a matter of supreme indifference to everyone concerned.

The centre of gravity of an ordinary cargo carrier may vary anywhere between ·62 and ·7 of the moulded depth; usually for modern one, two, three or spar decked ships having poops, bridges, and forecastles, the first figure is nearer the mark.

In light condition the G.M. or measure of initial stability works out at about 12 ft. in cargo steamers of the latest type.

Take an instance selected at random

from the tabulated data of a large number of steamers, a vessel 325 ft. by 46 ft. 10 in. by 26 ft. 10 in. The actual metacentric height measures 11 ft. 6 in. at light draught, that is, the ship ready for sea with fresh water on board, but no bunker coal or stores. At load draught the G.M. drops to about 2 ft. 9 in. with a homogeneous cargo of just sufficient density to completely fill the holds and to immerse her to the load draught.

Authorities differ as to the correct measure of initial stability necessary to ensure absolute safety under the various conditions of lading a ship experiences during her career, and to ensure sea-kindliness. Many consider 2 ft. a standard below which it is not advisable to go, while others maintain that 1 ft. is sufficiently adequate, indeed several cases have come under the author's notice of vessels possessing less than 1 ft. G.M., and without exception these have proved to be most comfortable sea-boats. Whichever figure is decided upon, there still remains a very great difference between that and the amount possessed by the above examples.

Within the last two years or so, the tendency has been to further increase beam, without in any way increasing draught; in fact, such at present is hardly permissible for general trading purposes, as the depth of water in the majority of ports precludes any such increase.

For some reason or other, beam has been fixed on as the elastic dimension, and has been stretched to a degree which scarcely favours the turning out of vessels possessing the lightest weight of hull for cargo carried. This great proportion of beam and fulness of form common to the great majority of cargo steamers produces an excessive amount of G.M. which aggravates rolling in a sea-way and destroys all features of sea-kindliness, besides bringing heavy strains to bear on the ships' structures, and rendering them most uncomfortable.

It may be argued, in many trades, that cargoes of such a density may have to be loaded as to necessitate a portion being carried on decks in order to bring the vessel down to somewhere near her Plimsoll marks, as in cases in which vessels have to carry timber.

Assume that this condition will be met with in the above-mentioned instance: the effect of a deck cargo will be to move the common centre of gravity vertically about 1 ft. 3 in. above its original position, leaving a metacentric height of about 1 ft. 6 in.

In view of the fact that a considerable number of vessels put to sea with the centre of gravity approaching the metacentre within much closer limits, and have proved themselves by long experience to be excellent sea-boats, there are indications that, for vessels employed outside of the timber trade, it would be profitable to diminish beam, and indeed, in many instances where deck cargoes of timber, machinery, &c., &c., are carried, it would most probably be found that a slightly diminished beam would in no way interfere with the seagoing qualities or safety of the vessel, whilst it must be obvious to everyone that a vessel possessing suitable proportions of length, breadth and depth, will undoubtedly be more capable of maintaining reasonable headway in heavy weather than one in which beam reaches are abnormal ratio; further, experience has shown that length is favourable to the maintenance of speed.

It is interesting to note that a new type of steamer has recently been evolved on the north-east coast, in which side tanks are fitted at the top sides as shown on diagram 4, with the two-fold object of immersing the vessel, when travelling lightship, to such an extent as to submerge the propeller in order to minimise racing whilst encountering head seas, and to reduce what has already been recognized in some quarters as an excessive amount of initial stability or metacentric height when light. The sloping sides form the bottom of the water ballast tanks, and also convert the steamer into one of the self-trimming type.

The conditions governing the actual forms are as many and varied as those

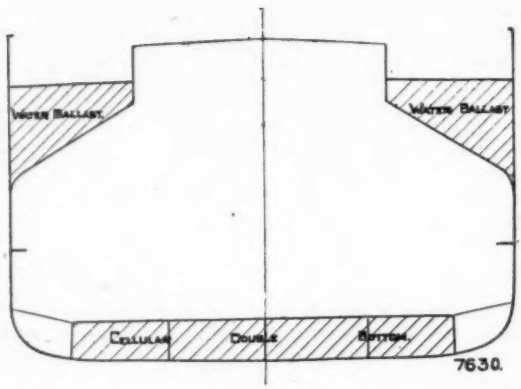



FIG. 4.

governing dimensions. Each particular class possesses features distinctive to itself, though there are two distinct headings under which this requirement may be grouped, viz., vessels which travel at a high rate of speed and those in which cubic capacity is of primary, whilst speed is of only secondary consideration. The latter may be subdivided into those which carry deadweight cargoes and those for light measurement goods.

As mentioned earlier, war and high-class passenger ships must, owing to the nature of their service, possess high speed, hence the general form is made as fine as possible with due regard to the previously mentioned requirements.

The form of cargo vessels pure and simple is, on the other hand, generally determined by considerations of deadweight to be carried, and capacity consistent with the lightest weight of hull, so that the scope for exercising ingenuity in devising forms is narrowed down very considerably, though there are, of course, certain general principles which must—or ought—to be adhered to.

The midship section, see diagram 1, very closely approximates a rectangle; a small amount of rise of floor is given to enable loose water to drain to the centre line, in the proximity of which are placed suctions to pump the tanks dry, and the bilge is given an easy round. Tumble home may or may not be a feature of the section, according to the fancy of the designer or to the consideration governing scantlings.

In order that displacement and capacity may be attained on as small dimensions as possible, the midship section is continued as far forward and aft as practicable and consistent with sweet lines.

Experiment has demonstrated and experience confirmed that a full fore body relative to the after body results in a more economical form for propulsion. The well-known parallel that a wedge driven blunt end through the water requires a less expenditure of power than one driven point first illustrates this principle.

Imagine a propeller placed just clear of the actual deadwater, it can be readily recognized without the aid of any elaborate mathematical formula that the resistance will be further greatly increased.

The action of the propeller on a ship in drawing a mass of water towards itself increases the speed of the water past the ship's skin, and the fuller the run the greater the augmented resistance, so that it may be laid down as a general principle that the centre of gravity of the displaced water—or the centre of buoyancy—should be a certain distance forward of midships; in practice this usually amounts to about 2 ft.

The forward sections particularly, and to an only somewhat lesser degree the after sections also, should be more or less club-footed in order to provide as much buoyancy as possible low down in the water, so that, when the ship is pitching, and the ends alternately out of and then buried in the sea, sufficient upward support may be given to prevent any undue plunging, while to throw the water away from, rather than on to the decks, a considerable amount of flam or flare should be given forward, and extending as far aft as the contour of the lines will permit.

The after sections owing to their inherent shapes fulfil this requirement.

Seamen speak in most feeling terms of vessels which bury their heads in every sea they encounter, a property which is entirely due to giving the forward sections a too pronounced fine V shape. The buoyancy of such a form does not make itself felt until a considerable proportion of the section is immersed, and the dynamic force gathered in the consequently greater downward plunge gives a still further immersion, so that by the time the plunge is arrested the deck ships heavy seas, and the vessel earns the sobriquet of a wet ship.

## Dover Harbour Works.—IV.*

*By W. NOBLE TWELVETREES, M.I.Mech.E.*

THE next feature of the new programme is the Transatlantic Station, to be built on the Admiralty Pier Extension, and occupying all the deep water section, except a portion at the end reserved for a battery and other naval purposes. As already shown, Railways Nos. 1 and 2 will be continued through and outside the Continental Station to the Admiralty Pier Extension, where Widening No. 2 will provide a deep water landing-stage for ocean liners. The Transatlantic railway station will be built parallel with the landing-stage, so that passengers may have adequate shelter and accommodation equal to that to be found in inland railway stations. Having regard to the fact that the station is to be situated nearly two-thirds of a mile out to sea, the buildings will not be of imposing character, but will include waiting-rooms, refreshment and cloak rooms, offices for the various shipping and traffic companies, and a department for the Customs' officials.

The third feature of the new programme is the ample space secured for the further development of goods traffic. Under the Act of 1891 the Harbour Board were empowered to reclaim five acres of land between the south pier of the Tidal Harbour and the Admiralty Pier for the purposes of a covered marine station. Thanks to the favourable settlement made with the Admiralty, a similar site will be made available for dealing with cargo after the land has been reclaimed by the building of Quays Nos. 2 and 3. The walls of these quays will enclose the shallow area and the existing sloping apron between the south pier and the Admiralty Pier. The apron, originally built for protective purposes, is rendered unnecessary by the shelter of the new works, and the shallow water area in the angle mentioned is equally useless. By filling it up a magnificent site will be made available for warehouses and offices, bordered by sheltered quays with about 20 ft. depth of water at low tide. The new area will be augmented by the construction of Quay No. 1, cutting off a triangular corner in the entrance channel to the tidal harbour, and by the construction of Quay No. 4 in that basin.

A new Commercial Station, established on these contiguous sites, would afford facilities for dealing with a large quantity of continental and ocean cargo, and, being conveniently situated for connection with both railway systems, would have a most important

* Article III. appeared in the previous number of THE ENGINEERING REVIEW.

bearing upon the future development of Dover as a commercial port. The details of the quays, warehouses, sheds, and equipment on the new site are not yet definitely settled.

It should be added that although the port authorities have given to the Admiralty the sole right to the use of the east side of the Prince of Wales Pier, they have by no means sacrificed their own right to use the western side of same pier for passenger and cargo traffic. As the structure in question has a total length of 3,180 ft., it is evident that its possibilities for the provision of additional quay accommodation are very great. This fact will be better realised by reference to Figs. 3 and 5 in article No. 1*. By the construction of a new landing-stage, similar to that now employed on the east side for ocean traffic, it would be easy to provide auxiliary berths for large steamers close to the existing Transatlantic railway station. If the pier were widened, in accordance with the powers already possessed by the Harbour Board, and the triangular area near the shore were reclaimed, a further site would be secured for wharves, warehouses, sheds, and other buildings, without interfering in any way with the newly-granted rights of the Admiralty, and the railway connections already made could easily be supplemented as required by the growth of traffic. This suggestion shows the great possibilities existing for future extensions of passenger and cargo traffic.

The net upshot of the agreement made between the Harbour Board and the Admiralty is that the size of the port will be increased by some ten acres of well-sheltered water, making the total area of the outer harbour about eighty-five acres; that ample space on shore and elsewhere will be rendered available with the railways which have long been urgently required to meet the requirements of traffic; and that further space will be secured for extension of the same facilities as occasion may demand.

* THE ENGINEERING REVIEW, Vol. xiii., pp. 225—227.

Notwithstanding the enterprise displayed by various steamship and railway companies in popularising different routes to and from the Continent, it is perfectly certain that the unique geographical position of Dover gives that port immense advantages in the eyes of British and foreign travellers. It is nearer to London and nearer to the Continent than any other seaport, two circumstances which appeal to people who are in a hurry, and to people who do not take kindly to the sea. For these reasons the Continental traffic of Dover shows continued increase, and the progressive improvement of the steamers engaged in the cross-channel service has conduced very largely to this satisfactory result.

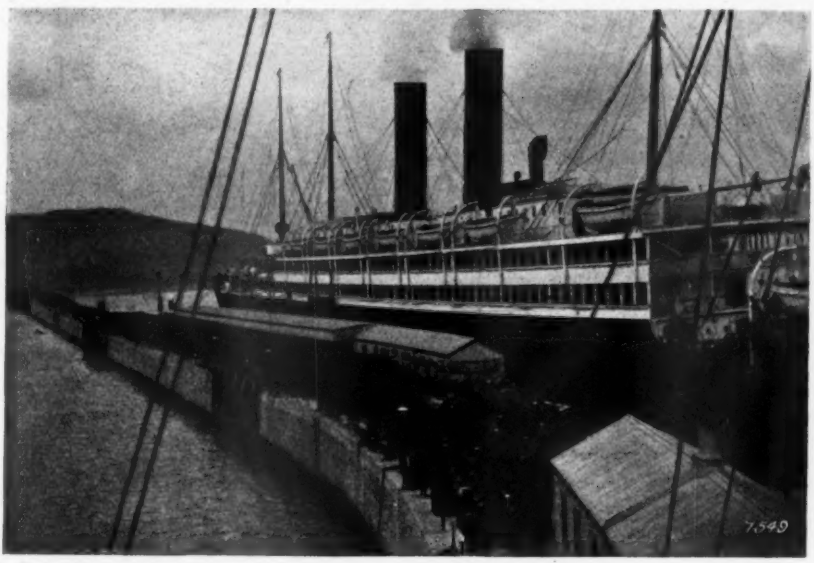
The South Eastern and Chatham Railway run one of their new turbine steamers between Dover and Calais, performing the trip in less than one hour, and one of their fast paddle steamers on the same service. Two of the mail steamers of the "Chemin de Fer du Nord" also ply between Dover and Calais, and with the vessels of the English companies provide a service of six passages daily. In addition to these facilities, the Belgian State Mail Packets provide another service of six passages daily between Dover and Ostend, so that, altogether, twelve Continental passenger steamers enter and leave the port every day.

Let us now consider briefly the position of Dover as an ocean port, for which it is clearly marked out by nature. The proximity of Dover to London and the Continent alike is a factor of much potency in relation to passenger traffic between Continental Europe, Great Britain, America, South Africa, and the East.

Dover is absolutely on the high road of traffic between the East and the West. All the great ocean liners traversing the North Sea actually pass within two or three miles of the harbour, whereas the ports of Southampton, Cherbourg, and Havre lie at a considerable distance from the direct route. The credit of recognising and utilising this favourable position

of Dover is largely due to Sir William Crundall, the Acting-Chairman of the Harbour Board, who obtained an interview with the German Emperor, at which were present the chiefs of the Hamburg-Amerika and Nord-Deutsche lines. The result was an arrangement that the vessels of the former company should call at Dover, and so began the career of the new ocean port of call.

Very large estimates have been made by American and German shipping experts as to the number of Transatlantic passengers that may be expected to embark and disembark at Dover during the year. The writer does not quote these because he wishes to avoid any



FIRST CALL OF HAMBURG-AMERICAN LINER "AMERIKA" AT DOVER, ON HER MAIDEN VOYAGE ON OCT. 12TH, 1905.

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Up to the present the transatlantic traffic has been almost entirely in the hands of Germans, and its proportions have been limited by the inadequate accommodation provided by the Prince of Wales pier, a point which is distinctly suggested by the illustration showing the *Amerika* alongside the pier on the occasion of her first voyage in October last. The latter drawback will be removed by the construction of the new landing stage and Transatlantic railway station on the Admiralty Pier Extension, which will permit a larger number of vessels to be dealt with, and so enable British steamship companies to complete pending arrangements for using the port.

appearance of exaggeration, but if prospective passengers to and from America and other parts of the world are taken into account there will evidently be a very large increase of the present figures, and it is impossible to say to what dimensions the traffic may be developed.

Reference was made in the preceding articles to the immense capacity of the National Harbour, the convenience of which will be increased by the new arrangement to keep war vessels and passenger steamers separate by utilising the Prince of Wales Pier as a partition.

Dover now possesses the second largest torpedo-proof harbour in the world, with 300 acres of water 6 fathoms or more deep, and 310 acres of more shallow water. To provide for the accommodation of war vessels, moorings have been laid over this vast area, and the Admiralty are engaged in completing all necessary defensive works. New forts mounted with 12-in. guns are to be constructed on the heights commanding the channel to the east and west, and suitable defences will be provided elsewhere. The heads of the Admiralty Pier, the East Pier, and the ends of the southern breakwater will be equipped with electric hauling gear, so that wire hawsers, leading through hawse pipes already built in, may be drawn across the two entrances if occasion should demand. It is probable also that docks for submarines will be constructed, similar to those already existing at Portsmouth and Plymouth, and that extensive storeyards will be established in positions where they will be safe from attack and convenient for the supply of vessels.

At the present time the Admiralty Harbour is not quite enclosed, as the southern breakwater remains to be completed. Unparalleled progress is being made with this portion of the works, twice as many concrete blocks having been laid during the past twelve months as in any previous year. A second traverser for the "Hone" grabs has recently been erected on the first "Goliath" crane employed in dredging the foundations. The practical effect of this has been to release the second "Goliath" for other work. A staging has also been erected for the shed accommodating the air compressors for the diving bells employed in levelling the foundations. The necessity for this staging arises from the huge volumes of water sweeping over the breakwater in heavy weather, as if the machinery were established on the masonry it would in all probability be carried away. It is hoped that the piling will be finished in August, the foundations in September, and that the great harbour will be enclosed above low water level, if not to a higher level, during the succeeding month of October. Then the completion in due course will readily follow.

The final form of the eastern entrance to the harbour still awaits settlement by the Admiralty. It has been observed that when the ebb tide is running, a strong current is established across this entrance from the direction of the shore, and the idea has been suggested that it would be desirable to alter the original configuration so as to direct this current into the harbour, and thereby to facilitate the entrance of vessels as well as to operate in preventing the deposition of silt. At the time of writing no decision has been made by the Admiralty on this point.

# The Design and Construction of Mechanical Calculators.—I.

*By WILLIAM J. GOUDIE, B.Sc., A.M.I.Mech.E.*

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In an article which appeared in the March issue, the writer showed how any factorial expression could be easily and quickly embodied in graphical form on a logarithmic chart; and in response to requests by readers of the review, he now proposes to deal with the mechanical analogue of the chart, the scalar calculator. The ordinary single-slide rule, which now forms part of the necessary equipment of every up-to-date engineer, is a very serviceable instrument for the majority of simple calculations involving continued multiplication and division and the extraction of square and cube roots; but for the more complex types of engineering formulæ it is not suitable. Within the past few years several modifications of the ordinary rule, provided with auxiliary attachments such as log-log scales, radial cursors, &c., have appeared. They are designed with a view to extend the scope of the instrument, and thus facilitate the solution of intricate expressions, and are excellent as far as they go; but for the rapid manipulation of any factorial expression of frequent occurrence, whose factors have integral and fractional exponents, the special compound instrument is preferable to any such modification of the single-slide one. By the provision of a separate scale for each factor involved, the actual or absolute values of the factors and the effect of varying one or more of these can at once be ascertained by inspection, while the method of adjustment of the scales is usually so self-evident that the mental effort, required for the manipulation of the same calculation on a modified single-slide instrument, is practically eliminated.

The following notes will deal with the design and construction of compound scalar calculators, a branch of the subject on which so little published matter is to be found in this country, that it may be regarded as almost non-existent. The methods described are the outcome of the writer's practical experience of such design, and it is hoped that they may be found of service by those engineers who are desirous of manufacturing for themselves such special instruments as will be of service to them in their daily work.

A calculator of the scalar type is merely the mechanical embodiment of the principles of logarithmic computation, and nobody need attempt the construction of one who has not a clear understanding of these principles, and also the principle of mechanical addition and subtraction.

It will be necessary for the sake of continuity, when dealing with these fundamental essentials, to repeat, to some extent, what is already familiar to every engineer who makes use of a table of logarithms; but this subject-matter will be condensed into as small a compass as is consistent with clearness, and only those points which are of importance in the mechanical applications will be emphasised.

*Mechanical Summation.*—In arithmetic, the measure of a quantity of any kind is expressed by a number which indicates how many times some arbitrary standard unit of the same kind is contained in the quantity. In the case of the arithmetical processes of addition and subtraction,

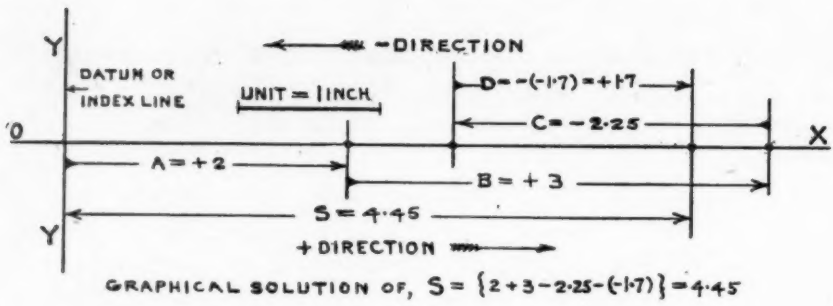



FIG. 1.

which may be classed under the general heading of "summation," such quantities are graphically represented by lines, usually, but not necessarily, straight, the numerical values of which are given by the number of times some arbitrary unit length is contained in them. The summation of any series of positive and negative quantities can be carried out graphically by drawing the lines end on end in positive and negative directions, and measuring the distance between the initial and final points, the measurement of the lengths throughout being done by means of a scale consisting of a series of consecutive unit lengths with equal sub-divisions. Thus, if $S = (A + B - C - D)$, the lengths respectively being $A = 2$, $B = 3$, $C = 2{\cdot}25$, and $D = (-1{\cdot}7)$, while the arbitrary standard unit is, say, one inch, then the graphical summation for $S$ can be carried out as shown in Fig. 1, which is self-explanatory, and is only one of several solutions depending on the chosen sequence of the terms.

Now, instead of marking off each length with a single scale, let a number of scales be used, and let each remain in position as the corresponding factor is entered in the solution, then the arrangement shown in Fig. 2 will result.

In the first case $O\ X$ is a fixed line on which all measurements are made, and in the second case the edge line of the scale, on which the initial value $A$ and final value $S$ are read, takes its place.

The datum line $Y\ Y$, relatively to which all positive and negative measurements are made, is the line of zero value of this scale, and in what follows will be termed the "index line." The other three scales, which are movable relatively to this scale, may be placed initially edge on edge with their index lines coincident with $Y\ Y$. By the displacement of the first movable scale to the right until its index line coincides with

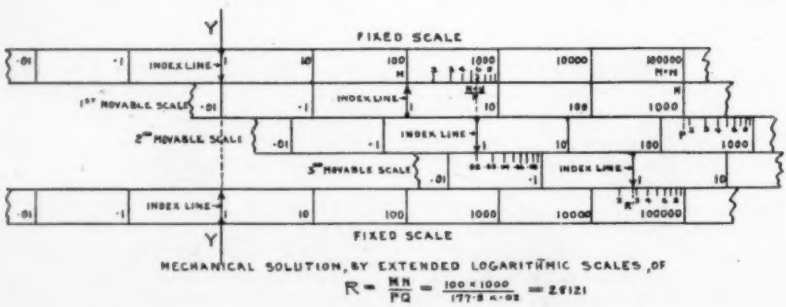



FIG. 2.

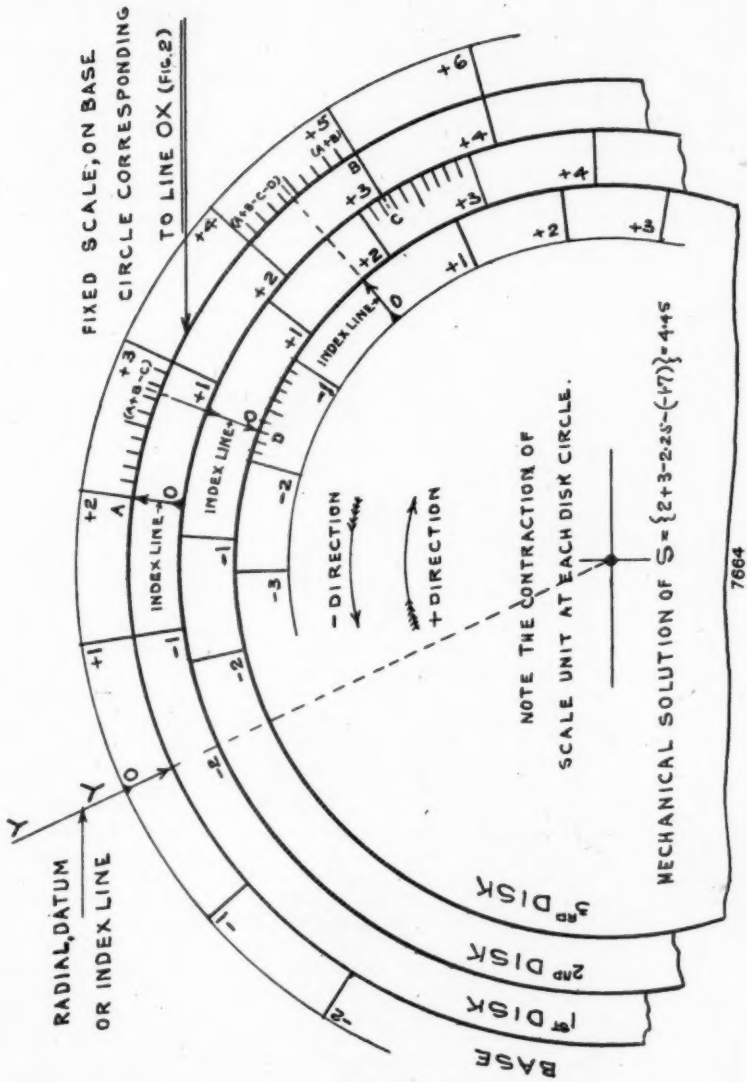

FIXED SCALE, ON BASE CIRCLE CORRESPONDING TO LINE OX (FIG. 2)
RADIAL, DATUM OR INDEX LINE
INDEX LINE
INDEX LINE
INDEX LINE
- DIRECTION
+ DIRECTION
NOTE THE CONTRACTION OF SCALE UNIT AT EACH DISK CIRCLE.
MECHANICAL SOLUTION OF S = {2+3-2.5-(-1.7)} = 4.45
7664
BASE
1ST DISK
2ND DISK
3RD DISK

FIG. 3.

$A = 2$ on the fixed scale, the value of $(A + B) = 5$ becomes determinate on the fixed scale from the position of $B = 3$ on the movable one. By moving the second scale, till the value of $C = 2{\cdot}25$ on it coincides with $B = 3$ on the first movable scale, and therefore comes in line with $(A + B) = 5$ on the fixed scale, the value of $(A + B - C) = 2{\cdot}75$ becomes determinate on the fixed scale from the position of the index line of the second movable scale. Finally, by moving the third scale till the value of $D = (-1{\cdot}7)$ on it is coincident with the index line of the second movable scale, and therefore in line with $(A + B - C) = 2{\cdot}75$ on the fixed scale, the value of the sum $S = (A + B - C - D) = 4{\cdot}45$ is determined on the fixed scale, in line with the index line of the third movable scale. If another fixed scale is introduced having its index line coincident with $Y\ Y$ and edge to edge with the third movable scale as shown, the final result can be more quickly and conveniently read on this scale than on the upper one.

This simple example shows, that when two quantities are added, the index line of a movable scale must be placed against one of the quantities on a fixed scale, and the sum will then be located on the fixed scale opposite the other number on the movable one.

Conversely, when two quantities are subtracted, the quantity to be subtracted must be placed against the other quantity on the fixed scale and the difference will then be located on the fixed scale, opposite the index line of the movable scale. It will be evident, that for a continuous process of addition and subtraction, where only one fixed and one movable scale are used, several intermediate settings and readings are necessary, while, with the series of movable scales illustrated here, by placing the values of the separate factors against one another, or against the index lines in accordance with the positive and negative convention the final result can be obtained at one setting, without any intermediate reading.

In this illustration five factors are involved. Two of these, the initial and final values, are read on the fixed scales, the remaining three are read on the movable scales. The value chosen to start the operation with may be regarded as an independent variable, the final value as the dependent variable, and the other quantities as arbitrary constants.

The fixed scale lines, therefore, in this mechanical arrangement take the place of the co-ordinate axes of the chart, and the movable scales become the equivalents of three series of curves of constant value. It was pointed out, in the case of the chart, that where $n$ factors are dealt with in a continuous solution, there require to be $(n - 2)$ sets of interlinked curves; and similarly, for a continuous mechanical solution involving $n$ factors, there require to be $(n - 2)$ interlinked and movable scales.

For this summation, straight lengths have been considered; but the straight edge-line of any one of these scales may be quite legitimately regarded as a portion of the circumference of a circle of infinite radius. When the radius becomes finite the scale-line assumes a definite curvature, but as this, on account of the constant radius, is the same at all points, it follows that the rotation of one scale arc, in coincidence with another of the same radius, will give exactly the same result as the relative displacement of the same straight-line lengths. This simple change from straight line to circle is of considerable importance in the design of scalar calculators, as will be seen later. In this modification, shown in Fig. 3, the movable scales have to be replaced by a series of disks having the same centre as the fixed scale circle. Although the operation of summation is not affected by the change, there has to be a proportional contraction of the unit length or arc of each circular scale as the disk radius decreases, since the linear or circumferential displacement of a point on any radial line, for a given angular displacement of the line, decreases as

the distance of the point from the centre of rotation decreases.

The necessary unit values of the three disk scales are easily obtained, by marking the base unit length on the fixed scale circle and drawing radials from its extremities; the intercept at any disk circle between the two radial lines is the proportional unit length at that circle. The subdivisions of the unit lengths can be obtained in the same manner from those of the base unit. This contraction of scale unit and its subdivisions has to be carefully attended to when logarithmic scales are used.

*The Logarithmic Principle.*—The connection between the mechanical principle of summation and the logarithmic one has now to be established, and for a clear demonstration of this a brief *resumé* of the principal properties of logarithms is desirable.

By definition, the logarithm of a number is the index or exponent of the power to which some arbitrarily chosen quantity called the "base" must be raised, in order to produce this number.

Thus, if $M = a^x$, then $x$ is said to be the logarithm of $M$ to the base $a$, and this statement is concisely expressed by $log_a M = x$. According to the algebraical "index law," when one power of a quantity is multiplied by another power of the same quantity, the exponent of the power of the product is given by the sum of the indices of the powers. Conversely, when one power is divided by another, the exponent of the quotient is given by the difference of the indices.

Let $\left.\begin{matrix} M = a^x \text{.....(1)} \\ N = a^y \text{.....(2)} \end{matrix}\right\}$ Multiply (1) and (2) and it follows from the above law that $M N = a^{x+y}$, and from the definition of the logarithm that $(x + y)$ is the logarithm of the product to the base $a$, that is, $log_a M N = (x + y)$. But $x = log_a M$ and $y = log_a N$, hence $log_a M N = log_a M + log_a N$.

Next divide (1) by (2), and it follows that $\frac{M}{N} = a^{x-y}$, and $log_a \frac{M}{N} = log_a M - log_a N$. What holds for two factors can easily be shown to hold for any number, so that the following general rule for multiplication and division by logarithms results. The logarithm of the product of any number of factors is the sum of the logarithms of the factors to the same base; the logarithm of the quotient is the sum of the logarithms of the numerator factors minus the sum of the logarithms of the denominator factors.

For the "common" system of logarithms the value which has been chosen for the arbitrary base $a$ is 10. In works on algebra it is shown that any quantity raised to zero power is unity, so that if this quantity is taken as 10, then $10^0 = 1$; also $10 = 10^1$, $100 = 10^2$, $1{,}000 = 10^3$, and so on. Hence, per definition, it follows that with 10 as a base the logarithm of any number between 1 and 10 is greater than 0 and less than 1, that is, it is wholly fractional; the logarithm of a number between 10 and 100 is greater than 1 and less than 2 or (1 + some fraction); between 100 and 1,000 the logarithm is greater than 2 and less than 3 or (2 + some fraction), and so on. The integral part of the logarithm is called the "characteristic," and the fractional part the "mantissa." What is termed a "table" of common logarithms is not a complete table, as only the mantissae or fractional portions of the logarithms are given, and the characteristics have to be ascertained by inspection of the numbers. Whether the characteristic is 0, 1, 2, &c., depends on whether the number is between 1 and 10, or 10 and 100, or 100 and 1,000, &c. The working rule, which follows from this, is to make the value of the characteristic of the logarithm of any quantity which is greater than unity less by one than the number of integral figures in the quantity. The reverse process has to be adopted when the logarithm is given, and the number or antilogarithm has to be ascertained. The significant figures of the number are given in an antilogarithm table, and the rule for the location of the decimal place is to point off from left to right between the first and second, or second

and third, or third and fourth figures, &c., according as the characteristic is 0, 1, 2, &c.

When the number is fractional, it follows directly from the "index law" that the logarithm is negative, for $\cdot 1 = \frac{1}{10} = 10^{-1}$, $\cdot 01 = \frac{1}{100} = 10^{-2}$, $\cdot 001 = \frac{1}{1000} = 10^{-3}$, and so on. In practice it would be most inconvenient to have two sets of mantissae values, one positive and another negative, and hence the negative mantissa value is transformed into a positive quantity by subtracting 1 from the negative characteristic, and adding 1 to the negative mantissa, a give-and-take process that does not alter the value of the whole logarithm. The mantissae values in the logarithm table are then equally valid for integral and fractional numbers, a circumstance which facilitates arithmetical calculation, and is of importance in the case of the mechanical analogue, the scalar calculator. The working rule which results from this modification is to make the negative characteristic, one more than the number of cyphers between the decimal point and the first significant figure to the right of the decimal point. Conversely, to obtain the number from the logarithm, the number of cyphers to be added between the decimal point and the first significant figure is one less than the value of the negative characteristic.

There remains the important property of the logarithm, which enables the operations of "involution" and "evolution" to be performed with ease and rapidity, and for whose mechanical manipulation the compound type of calculator is superior to the single slide instrument.

If each side of the equation $M = a^x$ is raised to the same power $k$, then, according to another reading of the "index law," $M^k = a^{kx}$, that is, $log_a M^k = k \, log_a M$. If $k$ is integral the process is that of involution, if it is fractional it is that of evolution.

Each of these cases is covered by the statement that, the logarithm of a number raised to any power is the product of the index of the power and the logarithm of the number.

*The Mechanical Adaptation of the Logarithmic Principle.*—Reverting now to the figures used in the mechanical illustration, it will be seen that $A = 2 = \log. 100$, $B = 3 = \log. 1000$, and from a table of antilogarithms that $C = 2{\cdot}25 = \log. 177{\cdot}8$, and $D = (-1{\cdot}7) = (-2 + {\cdot}3) = \log. {\cdot}02$ approximately, while the result $S = 4{\cdot}45 = \log. 28{,}121$.

It will be evident from a consideration of these figures that a more practical significance is given to this summation, if the quantities added and subtracted are regarded as the logarithms of certain numbers, say, $M$, $N$, $P$, $Q$, and result $R$. By the simple change of statement the primary mechanical operation of addition and subtraction becomes, relatively to these numbers, one of multiplication and division, since $\log. R = (\log. M + \log. N - \log. P - \log. Q) = \log. \frac{M\ N}{P\ Q}$ is the logarithmic equivalent of the factorial expression $R = \frac{M\ N}{P\ Q}$. The corresponding change in the mechanical arrangement is the substitution of logarithmic for uniform scales. The method of deriving the logarithmic scale from the primary uniform one, a clear idea of which is essential for the successful design of a scalar calculator, is shown in Fig. 4.

Since the value of the logarithm of an integral number is positive, and that of a fractional one negative, it follows from the positive and negative convention that the logarithms of integral numbers should be set off to the right, and the logarithms of fractional numbers to the left of the datum or index line $YY$. The unit divisions of the primary scale on the right are + 1, + 2, + 3, &c., and therefore represent the logarithms of 10, 100, 1,000, &c., while those on the left are — 1, — 2, — 3, &c., and therefore represent the logarithms of ·1, ·01, ·001, &c. These divisions may be figured log. 10, log. ·1, &c., but as the "log." prefix is obviously superfluous it is always omitted, and only the

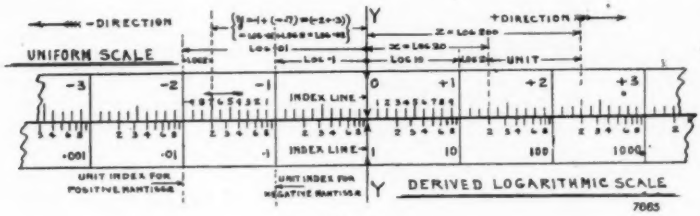



FIG. 4.

figures are marked as shown. To the right of *Y Y*, the logarithmic value of any number between 1 and 10 will then be located within the first unit length, that of any number between 10 and 100 within the second unit length, and so on. Similarly to the left of *Y Y* the logarithmic value of any fraction between 1 and ·1 will be located within the first unit length, that of one between ·1 and ·01 within the second unit length, and so on. On the uniform scale then, each unit division line to the right of *Y Y* also represents the characteristic of a logarithm, and the succeeding decimal part of the unit, read from left to right, or in the positive direction, is its mantissa value. Thus, on the uniform scale the third division of the second unit length or ·3 of the unit is approximately the value of log. 2; the initial or index line of the unit length is 1 or log. 10, so that the logarithmic value represented by the distance $x$ is (log. 10 + log. 2) = log. 20.

Taking the third division of the next unit length the distance from *Y Y* is thereby increased by unity or log. 10, so that this division is $z$ = (log. 20 + log. 10) = log. 200. If this process of deduction is applied to each of the equal dimensions of the unit lengths it will readily be seen that the derived logarithmic scale can be obtained from the uniform one by simply working the mantissae values of 2, 3, 4 . . . 10 in each unit length at the corresponding decimal divisions of the unit.

The derived logarithmic scale, set out in this matter, then takes the form of a series of consecutive unit lengths, each unit being divided into nine unequal parts gradually decreasing in magnitude from left to right.

If the mantissae values of the logarithms of fractional numbers were retained in their negative form, the subdivisions of the units of the uniform scale to the left of *Y Y* would require to read in ascending order from right to left, or in the negative direction like the unit lengths, in order to obtain the negative mantissae values; and such an arrangement would be just as awkward for mechanical as for arithmetical calculation.

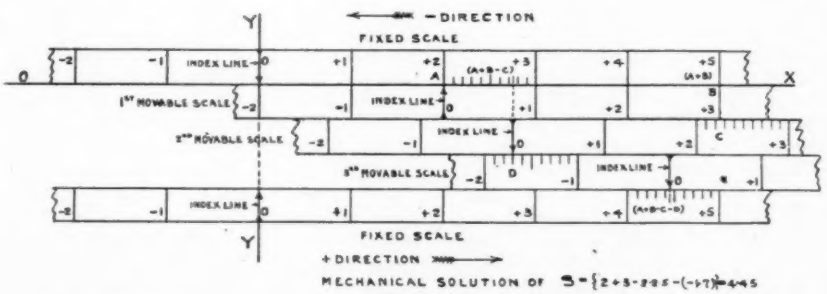



FIG. 5

In this case log. ·02 would be approximately $(-1{\cdot}7)$ or $(-1)+(-{\cdot}7)$, and the ·7 mantissa value would be reckoned from the $-1$ unit value to the left; but by the subtraction of 1 from the negative characteristic this value is changed to $-2$, or graphically, the index of the unit is transferred from the right to the left hand vertical, while the compensating addition of 1 to the negative mantissa transforms it from $-{\cdot}7$ to $(1-{\cdot}7) = +{\cdot}3$, the graphical interpretation of this arithmetical change being that the positive mantissa value, from the logarithm table, is read from the new index of the unit in the positive direction, as in the case of the logarithm of an integral number. The logarithmic value, therefore, expressed by the distance $y$ is $(-2+{\cdot}3)$ or $\bar{2}{\cdot}3$, and is approximately that of the fraction ·02. All other negative values can be dealt with in the same manner. As a result of the foregoing considerations, the following general rule for the construction of a complete logarithmic scale may be formulated. Lay out on the scale line a consecutive series of unit lengths. On one unit length mark the nine mantissae values of (2, 3, 4 . . . 10) reading from left to right. Apply this length to each unit in succession and transfer the mantissa-divisions. Choose any one of the unit division lines as the primary datum line $Y\,Y$ or value of log. 1, mark the successive unit divisions to the right of $Y\,Y$, 10, 100, 1,000, &c., and those to the left, ·1, ·01, ·001, &c., then figure the corresponding fractional values on the sub-divisions of each unit length.

Such a complete or extended logarithmic scale is necessary for the special calculator, where the actual values of the factors are to be ascertained directly. The scale of the ordinary slide rule is merely one unit length, and may be regarded as any of the units of the above scale, and its index line, or the left hand vertical of the instrument, may be given any arbitrary value, such as 1 or 100, or ·1, or ·01, according as the number to be read on it is integral or fractional. The variable value of the index line, and the dependent values of the sub-divisions of the unit length necessitate various rules for the location of the decimal point, in results obtained from this instrument.

The original series of uniform scales, transformed into complete logarithmic ones, in the manner explained above, and having their index lines in exactly the same positions as in Fig. 2, are shown in Fig. 5, the transformed combination now giving directly the mechanical solution of the equation

$$R = \frac{M\,N}{P\,Q} = \frac{100 \times 1000}{177{\cdot}8 \times {\cdot}02} = 28121.$$

The circular scale and disk arrangement in Fig. 3 can be transformed in a similar manner to give this solution.

An inspection of this combination will show that the rule of adjustment for the mechanical multiplication or division of any two factors, by means of a fixed and a movable scale of logarithms, is simply a repetition of the rule for addition and subtraction, evolved in connection with the arrangement of uniform scales in Fig. 3, with the exception that multiplication and division are substituted for addition and subtraction, and product and quotient for sum and difference.

So far, only the mechanical adaptation of the principle of logarithmic computation, for the performance of the simple operations of continued multiplication and division, has been considered.

In the next article, the more difficult "general case" of any factorial expression having factors with any integral or fractional exponents, and therefore involving the additional processes of involution and evolution, will be discussed.

# Locomotives at the Milan Exhibition.

*By CHAS. R. KING.*

At the exhibition of Milan, which this year celebrates the opening of the Simplon route to Italy, the one principal feature of the show is the railway section. Locomotives, modern rolling stock and railway machinery form an exhibit of more importance than anything similar which has been brought together on the Continent, except the great railway exhibition at Vincennes, Paris, in 1900. At the Paris show there were forty-two main line, or nominal gauge, large locomotives, while at Milan there are forty of this category and about ten or twelve of narrow gauge, or light motors, of various kinds. Considered solely by the aggregate tractive power represented, the Milan exhibition is of more importance than any other yet held in Europe. This is easily understood, simply from the enormous extension in the practice of building four-cylinder engines, and these, with scarcely an exception, all compound. The reader can form, from the accompanying lists of the chief mechanical features, an adequate idea of this development of the compound locomotive and of the particular form which this system is taking, including the mechanism adopted. It will be observed that there are twenty-six compound engines, of which number eighteen are four-cylinder engines, while there is in addition one four-cylinder single-expansion engine (experimental).

Care is necessary to avoid presuming that these figures of the Milan exhibition are absolutely indicative of general practice on the Continent. Exhibitions are not the place to gather such statistics. Take as an instance: the German section is represented almost wholly by Prussian makers building for the Prussian railways. That means single expansion and rather backward ideas. The best and most progressive builders in Germany have abstained from participating in this exhibition. Had such firms exhibited, Germany as a whole would have shown not only as a great exponent of the four-cylinder compound system (including superheating), but also as the most progressive and original of all the countries exhibiting at Milan. Italy also makes a rather inferior exhibit not thoroughly representative of its present practice. It has no engines to spare, having either to borrow or buy up old machines to keep traffic going, more or less, during the exhibition year. Properly represented, it would have exhibited nearly all four-cylinder compounds, latest models of the "Adriatic" arrangement. The result is that there are only twenty-six compound engines, including small engines, as compared with twenty-six (out of the forty-nine engines of all sorts and sizes) shown at Paris in 1900. Of the four-cylinder compounds a goodly number represent no radical advance in engine system beyond that which was already common at periods of seventeen and fourteen years ago, such examples being found in the French, Swiss and Belgian sections; but in general, taking all sections together, there has been great progress since 1900—immense progress it might have been said—if the German section had been properly representative of all German States. By reason of these abstentions Austria, Belgium, Hungary, and Italy take the lead for constructional progress. The older types exhibited have the high pressure and low pressure engines driving upon different axles, the cylinders being disposed according to the "Webb" earliest arrangement, but with the mechanism of the "de Glehn" types, including of course two sets of valve gears. An advance upon this is seen in two engines,

the P.L.M. Series 25, and the Belgian States Series 19A. We have in England an example of these latter types built by the Great Northern Railway Company. The rest of the engines represent the progressive practice of central Europe with four cylinders all in one cross line, all pistons driving on one pair of wheels, and one set of valve gear actuating four valves. In England the equivalents of these engines are the "Webb" four-cylinder locomotives (N.W.R.) and the "Worsdell" four-cylinder locomotives (N.E.R). It is, in fact, the one engine arrangement for four-cylinder compounds which is rapidly becoming universal. The crank axle in all the modern engines with scarcely any exceptions is of the "Z" or oblique type. Built-up axles are not employed. The valve gear is always the Walschaerts's. For the sake of additional lightness (of such vital importance in central European practice) solid or plain bushed ends for coupling rods are being adopted, although their want of adjustment has hitherto been much disapproved. Piston valves show continuous increase of application. They are thought to be indispensable for superheated steam, but in the great engines of the Austrian State Railways Mr. Goelsdorf has introduced a boiler-barrel superheater all in retaining flat valves. Both Mr. Goelsdorf and Mr. Alfred G. de Glehn are reluctant to adopt piston valves; and as so many engines at Milan are built more or less according to the ideas of these engineers the exhibition does not really represent an equivalent general practice in this matter. In the Italian section the combined high-pressure piston valve and low-pressure flat valve is old practice: in future piston-valves (two for four cylinders) will be employed for all large engines. Using superheated steam of 228 lbs. and 235 lbs. respectively, it is worthy to observe that the ratio of high-pressure to low-pressure cylinders in the huge Belgian, and Austrian engines varies from 1 : 2·91 to 1 : 2·93. The most recent type of express engine at Milan (Hungarian State) has a ratio, high-pressure to low-pressure cylinders, of 1 : 2·98. These proportions realise, with an efficient utilisation of the steam, an even drop in the receiver pressure, so reducing back-pressure on the high-pressure pistons. The proportions of all steam passages—valve ports, &c.—are duly calculated for the weight of steam to be passed by them at the highest piston speeds, while the total clearance volumes are made very great by the unusual capacity of the low-pressure steam ports, so avoiding excessive compression. It is an admitted fact that compounding with two, three or four cylinders has never, at its origin, met with a reasonable degree of success in England, and it is very doubtful if it is necessary to go beyond the question of these proportions to discover the principal causes therefor. The successful practice of compounding in central Europe has been such that we might now profitably, and without offence to our own ability, study in what manner the utilisation of the steam in the cylinders of our past or present compound engines has differed from that of countries where the compound engine has attained a very high degree of perfection.

Turning to locomotive boilers at Milan, it is seen that in all the most recent practice the firebox shell is curved to the contour of the boiler barrel, and that the barrel is straight. A conical barrel ring has been introduced in some of the Austrian boilers, as exists already in certain Italian locomotives, but this practice is henceforth to be abandoned in Italy: for a conical barrel, as it is obvious, reduces the total capacity of the boiler, and as the boiler is not to be considered simply as a generator, but as a reservoir of latent power, this contraction of the diameter is only admissible where the weight on the leading wheels would otherwise be too great. Flat-topped fire-box shells (to use the term employed in the country of their origin for modified forms of the firebox invented by Belpaire) are only seen here in French locomotives and in one or two Belgian locomotives built strictly to French designs. Wide fireboxes are becoming more and more common in nearly all countries exhibiting

## MAIN FEATURES OF THE LOCOMOTIVES AT THE MILAN EXHIBITION, 1906.

(ORDER OF SUCCESSION IN ENTERING AT THE PORTA BUONARROTTI.)

| Makers. | Railway. | Engine. | Wheel Type. | Engine Type. | Adjuncts. | Valve Type. | Valve Mechanism. | Rocking Transmission. | Boiler. | Tender Peculiarities. |
|---|---|---|---|---|---|---|---|---|---|---|
| **BELGIUM.** | | | | | | | | | | |
| Cockerill ... | Belgian State | 4-cyl. compound series 19 *bis.* | 4-6 | P. L. M. modified | Superheater (Cockerill's) | Piston | 1 set | Transverse | Caledonian modified | |
| La Meuse ... | ,, | 4-cyl. simple | 4-6 | Central European | Superheater of Belgian State and Schmidt | ,, | ,, | ,, | ,, | |
| Tubize ... ... | ,, | 4-cyl. compound series 8 | 4-6 | De-Glehn | — | Flat | 2 sets | None | flat-top narrow firebox | |
| St. Leonard ... | ,, | ,, | 4-6 | ,, | — | ,, | ,, | ,, | ,, | |
| Franco-Belge... | ,, | 2-cyl. simple series 35 heavy passenger | 4-6 | Caledonian modified | Superheater "Schmidt Belgian State" | Piston | — | — | Caledonian modified | |
| Haine-St. Pierre | ,, | 2-cyl. simple series 18 | 4-4 | ,, | ,, | ,, | — | — | ,, | |
| **AUSTRIA.** | | | | | | | | | | |
| Moravska works (Praha) | Austrian State | 4-cyl. compound series 108 | 4-4-2 | Central European | Goelsdorf starting | Flat | 1 set | Vertical | Round top fire-box over frames | Lozenge shape (bunker on top). |
| Floridsdorf ... | ,, | 4-cyl. compound heavy passenger series 110 | 2-6-2 | ,, | ,, | ,, | ,, | ,, | wide firebox | |
| Privilegirten A. G. Staats Fabrik | ,, | 4-cyl. compound mountain series 280 | 2-10 | ,, | Superheating "Goelsdorf" | ,, | ,, | ,, | half wide firebox | |
| Wienerneustadt (Sigl) | ,, | 2-cyl. compound mountain or goods, series 180 | -10- | — | Goelsdorf starting | ,, | — | — | ,, | |
| Krauss (Linz)... | Lower Austrian light railways (80 c/m gauge) | 2-cyl. compound | -8-4 | — | Superheater "Schmidt" | ,, | — | — | — | 4-wheel radial; part weight on engine. |
| Krauss... ... | Austrian State | 2-cyl. compound tank series 178 | -4- | | | | | | | |
| Komarek ... | — | 2-2-2 motor car | | | | | | | | |
| **FRANCE.** | | | | | | | | | | |
| Creusot ... | P.L.M. | 4-cyl. compound series 25 | 4-6 | Henry and Baudry | No intercepting valve | Piston | 2 sets (1 fixed) | Independent | Flat-top firebox | |
| ,, | P.L.M. (Algeria) | — | — | — | — | — | — | — | A water tube boiler | |
| Epernay ... | Est | 4-cyl. compound series 11. Express | 4-6 | De Glehn | — | "Est" Piston | 2 sets | — | Flat-top firebox | |
| Belfort (Société Alsacienne) | Est | 4-cyl. compound series 11. Tank | 4-6-4 | ,, | — | ,, | | — | ,, | |
| Ia Chapelle ... | Nord | 2-cyl. tank series 2 | 4-4-4 | | | | | | | |
| ,, | ,, | 4-cyl. compound express. Coal series 6 | 6-2+2-6 | Double motor bogie | — | Flat | ,, | Independent | Half wide firebox | |
| Belfort... ... | Etat (Algeria) | 2-cyl. passenger | 4-6 | — | — | ,, | | | | |
| Cail ... ... | — | 2-cyl. light railway motor | -4- | — | — | — | — | — | Vertical | |
| ,, | Damas to Ham | 2-cyl. engine | -8- | | | | | | | |

| Makers. | Railway. | Engine. | Wheel Type. | Engine Type. | Adjuncts. | Valve Type. | Valve Mechanism. | Rocking Transmission. | Boiler. | Tender Peculiarities. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | ITALY. | | | | | | |
| Breda ... ... | Ferrovie dello Stato | 4-cyl. compound series 690 (*Ex* Adriatica series 500) | 4-6 | Central European "Adriatic" system | — | Pistons (2) | 1 set | None | Half-wide fire-box | Cylindrical (bunker in cab). Engine runs fire-box in front. |
| Ansaldo-Armstrong | ,, | 2-cyl. (inside) compound (heavy passenger) series 630 | 2-6 | *Ex* Adriatica | — | Pistons (outside) | | | | |
| ,, | ,, | 2-cyl. compound tank series 910 | 2-6-2 | (Stato) | — | H.-P. Piston L.-P. Flat | | | | |
| Officine Meccaniche di Milano | ,, | 2-cyl. compound mountain series 750 | 4-8 | *Ex* Mediterranea | — | ,, | — | — | Wooten modified | |
| ,, | — | motor car | -4- | — | — | — | — | — | Transverse boiler | |
| Officine Meccaniche di Saronno | ,, | 2-cyl. compound series 320 | -6- | | | | | | | |
| Breda ... ... | ,, | 2-cyl. shunter series 835 | -6- | | | | | | | |
| | | | | HUNGARY. | | | | | | |
| Hungarian State Ry. Works | State | 4-cyl. compound express | 4-4-2 | Central European | — | Piston | 1 set | Transverse | Wide fire-box | Cylindrical (bunker on top). |
| ,, | ,, | 2-cyl. compound (industrial) | -8- | — | Klien-Lindner pivoting coupled axles | | | | | |
| | | | | GERMANY. | | | | | | |
| Hannoversche Maschinenbau A.G. | Prussian State | 4-cyl. compound express series S 7 | 4-4-2 | Central European | Von Borries' intercepting valve. | H.-P. "Lentz" poppets L.-P. Piston | 1 set Heusinger—Von Borries | Vertical | Wide fire-box | |
| ,, | Industrial | 2-cyl. tank | -6- | — | Superheater "Pielock" | Lentz horizontal poppets | Lentz linkless gear | | | |
| Schwartzkopff | Prussian State | 2-cyl. tank series T 16 | -10- | — | Smoke-box superheater ("Schmidt") | Piston | | | | |
| Breslauer A.G. | ,, | 2-cyl. express series S64 | 4-4 | — | ,, | ,, | | | | |
| "Vulcan" A.G. | ,, | 2-cyl. goods series G 8 | -8- | — | ,, | ,, | | | | |
| Henschel ... | ,, | 2-cyl. express series S 4 | 4-4 | — | ,, | ,, | | | | |
| ,, | ,, | 2-cyl. shunting | -4- | | | | | | | |
| ,, | Egyptian Government | 2-cyl. (inside) express | 4-4 | | | | | | | |
| Borsig ... ... | Anatolian railways | 2-cyl. compound goods | 2-8 | | | | | | | |
| ,, | — | Crane, tank | 2-4 | | | | | | | |
| ,, | — | Hot water locomotive | -4- | | | | | | | |
| Grafenstaden (Société Alsacienne) | Alsatian railways | 4-cyl. compound | 2-10 | "de Glehn-Midi" | — | Flat | 2 sets | None | | |
| ,, | — | 4-cyl. compound tank | 4-6-4 | de Glehn | — | ,, | ,, | ,, | | |
| | | | | SWITZERLAND. | | | | | | |
| Winterthur ... | Federal railways | 4-cyl. compound express | 4-6 | de Glehn | — | Flat | 2 sets | None | | |
| ,, | Gotthard | 4-cyl. compound express | 4-6 | ,, | — | ,, | ,, | ,, | | |
| ,, | Mountain lines | 2-cyl adhesion 2 cyl. rack-rail | -4- | — | — | ,, | | | | |

excepting France. If the wide fire grate is eventually adopted there, with the existing forms of fireboxes, this will simply mean the introduction there of the original "Belpaire" firebox. Only one water tube boiler is shown, this being the "Robert" type already in use on the Algerian lines of the P.L.M. Co.

Superheaters are applied to many locomotives. The Prussian State locomotives are, to the number of four, fitted with the "Schmidt" smoke-box apparatus, and the Belgian State locomotives are fitted, to the number of four, with the flame-tube superheaters of Schmidt and the Belgian State Railways. A light railway locomotive by Krauss in the Austrian section has the latter form of superheater. A "Pielock" superheater is built in the boiler of a small 6-coupled tank engine made by the Hannoversche A.G. Locomotive Works. This engine is in addition fitted with the "Lentz" poppet valve-gear and a novel valve-gear by Lentz.

One Belgian engine has the "Cockerill" superheater, and one Austrian engine has the "Goelsdorf" boiler-superheater. In the matter of superheaters the Prussian exhibit may be said to represent Germany entire, for in south Germany also these apparatus have recently been adopted. Of the results obtained much can be said for them and something against. It will need some years of practice before it can be established accurately that they represent a real total gain. The ideal apparatus is not to be seen here. In France and Italy the absence of these appendages appears to indicate caution. For the time being Germany and Belgium are the only two continental countries which have adopted this apparatus on an extended scale.

# Large Gas Engines built in Great Britain.

*By T. WESTGARTH.*

Most of the papers read and discussed at the recent meeting of the Iron and Steel Institute are dealt with by our Metallurgical Contributor, Mr. Percy Longmuir, in the section controlled by him, viz., "Metallurgical Progress."

Among the contributions placed before the meeting were two dealing with large gas-engines in Belgium and Germany and under these circumstances, it was considered advisable that some information should be given upon the same subject in Great Britain. This was undertaken by Mr. Tom Westgarth, and in view of the interesting and valuable nature of the information contained in his communication it has been deemed advisable to give this in full.—ED.

I give below schedules showing the number and particulars of large gas-engines which have been built or are building by British makers, and in view of the growing size of gas-engines I have concluded that engines less than 500 h.-p. cannot now be included in the category of large gas-engines, and therefore I have not considered engines under that power.

"OECHELHÄUSER" TYPE GAS ENGINES. BUILT OR BUILDING BY WILLIAM BEARDMORE & CO., LTD., GLASGOW.

| No. of Engines. | Indicated Horse-power Each. | Type. | Nature of Work. | Gas Used. |
|---|---|---|---|---|
| 6 | 2500 | Twin cylinder | Dynamo | Producer |
| 1 | 1850 | Single cylinder | Rolling-mill | ,, |
| 4 | 1250 | Twin cylinder | Dynamo | ,, |
| 2 | 1250 | Single cylinder | ,, | ,, |
| 4 | 625 | ,, ,, | ,, | ,, |
| 1 | 625 | ,, ,, | Rolling-mill | ,, |
| 1 | 625 | ,, ,, | Air compressor | ,, |
| 2 | 500 | ,, ,, | ,, ,, | ,, |
| 7 | 500 | ,, ,, | Cement-mill driving | ,, |

Total, 28 engines; 32,600 indicated horse-power.

"KÖRTING" TYPE GAS ENGINES. BUILT BY MATHER & PLATT, LTD., MANCHESTER.

| No. of Engines. | Indicated Horse-power Each. | Type. | Nature of Work. | Gas Used. |
|---|---|---|---|---|
| 1 | 1250 | Twin cylinder | Dynamo | Duff producer |
| 2 | 875 | Single cylinder | ,, | Mond producer |
| 2 | 625 | ,, ,, | ,, | Duff producer |
| 1 | 625 | ,, ,, | Flour-mill | Mond producer |

Total, 6 engines; 4,875 indicated horse-power.

"PREMIER" TYPE GAS ENGINES. BUILT OR BUILDING BY THE PREMIER GAS ENGINE CO., LTD., NOTTINGHAM.

| No. of Engines. | Indicated Horse-power Each. | Type. | Nature of Work. | Gas Used. |
|---|---|---|---|---|
| 2 | 1100 | Tandem, single-acting | Dynamo | Bituminous producer |
| 1 | 1000 | ,, ,, | Blowing | Blast-furnace |
| 5 | 650 | ,, ,, | Dynamo | Bituminous producer |
| 4 | 600 | ,, ,, | ,, | ,, ,, |
| 1 | 600 | ,, ,, | Rolling-mill | ,, ,, |
| 11 | 500 | ,, ,, | Dynamo | ,, ,, |
| 2 | 500 | ,, ,, | ,, | Coke-oven |
| 1 | 500 | ,, ,, | Paper-mill | Bituminous producer |
| 1 | 500 | ,, ,, | Dynamo | Blast-furnace |

Total, 28 engines; 16,950 indicated horse-power.

GAS ENGINES BUILT BY WILLANS & ROBINSON, LTD., RUGBY.

| No. of Engines. | Indicated Horse-power Each. | Type. | Nature of Work. | Gas Used. |
|---|---|---|---|---|
| 2 | 900 | Tandem, double-acting | Dynamo | Mason producer |

Total, 2 engines; 1,800 indicated horse-power.

GAS ENGINES BUILT OR BUILDING BY CROSSLEY BROS., LTD., MANCHESTER.

| No. of Engines. | Indicated Horse-power Each. | Type. | Nature of Work. | Gas Used. |
|---|---|---|---|---|
| 4 | 700 | Single-acting, *vis-à-vis* | Alternators | Producer |
| 4 | 700 | Single-acting tandem | Pumping | ,, |
| 4 | 625 | Single-acting, *vis-à-vis* | ,, | Coal-gas |
| 2 | 610 | Four cylinder single-acting, *vis-à-vis* | Alternators | ,, |
| 5 | 560 | Single-acting, *vis-à-vis* | Electrolytic work | Producer |
| 1 | 560 | ,, ,, | Wire work | ,, |
| 1 | 560 | ,, ,, | Bleach works | ,, |
| 1 | 560 | Single-acting tandem | Flour-mill | ,, |
| 1 | 560 | Single-acting, *vis-à-vis* | Blowing | Blast-furnace |
| 2 | 500 | ,, ,, | Electric lighting | Producer |
| 2 | 500 | Single-acting tandem | ,, ,, | ,, |
| 1 | 500 | Single-acting, *vis-à-vis* | ,, ,, | Coke-oven |
| 2 | 500 | ,, ,, | Electrolytic work | Producer |
| 1 | 500 | ,, ,, | Electric tramway | ,, |
| 1 | 500 | ,, ,, | Cotton mill | ,, |
| 1 | 500 | ,, ,, | Mining machinery | ,, |

Total, 33 engines; 19,360 indicated horse-power.

"COCKERILL" TYPE GAS ENGINES. BUILT OR BUILDING BY RICHARDSONS, WESTGARTH & CO., LTD., MIDDLESBROUGH.

| No. of Engines. | Indicated Horse-power Each. | Type. | Nature of Work. | Gas Used. |
|---|---|---|---|---|
| 2 | 1,500 | Twin tandem, double acting | Tube rolling-mills | Mond producer |
| 2 | 1,500 | " " | Dynamo | " " |
| 1 | 1,000 | Tandem, double-acting | Tube rolling-mill | " " |
| 2 | 950 | " " | Dynamo | Blast-furnace |
| 10 | 800 | Single cylinder, single-acting | Blowing | " |
| 1 | 800 | Tandem, single-acting | Mine fan | Coke-oven |
| 2 | 750 | Tandem, double-acting | Dynamo | Mond producer |
| 1 | 650 | " " | " | " " |
| 1 | 650 | " " | " | Blast-furnace |

Total, 22 engines; 20,500 indicated horse-power.

It will be observed no mention is made in the above schedules of engines built by Messrs. Hornsby of Grantham, Rodger & Co. of Glasgow, Campbell of Halifax, Fielding & Platt of Gloucester, the National Company of Ashton-under-Lyne, Tangyes of Birmingham, or the Westinghouse Company of Manchester, which is accounted for by the fact that none of these firms have as yet built engines of 500 h.-p. or upwards, although they are all building engines of fair size.

It will be noticed that all the British builders of large gas-engines are using the "four-cycle" system, except the builders of Körting and Oechelhäuser engines, who work upon the "two-cycle" system. It will also be noticed that large gas-engines are gradually coming into use in Great Britain for general purposes, *i.e.* in addition to blowing and dynamo work, they are being applied to rolling-mills and for general manufacturing purposes, cotton-mills, cement works, &c.

To illustrate the extent to which gas-engines of large size are now being used in Great Britain, I give illustrations of some of the principal installations in the country.

Fig. 1 shows the installation of of Oechelhäuser engines built by Messrs. Beardmore for their new shipyard at Dalmuir. This installation is of 6,625 indicated h.-p. in seven units.

Fig. 2 shows part of an installation of Körting engines by Messrs. Mather & Platt, consisting of two 875 indicated h.-p. engines now running at a chemical works.

Fig. 3. Engines supplied to Messrs. Bayliss, Jones & Bayliss by the Premier Co., the engine in the foreground being of 650 h.-p.; the other engines are less than 500 h.-p., and therefore do not come within the scope of this paper.

Fig. 4. One of a pair of 900 indicated h.-p. engines built by Messrs. Willans & Robinson, and running at Reading.

Fig. 5 is an illustration of one of Messrs. Crossley Brothers, latest engines, of 625 indicated h.-p.

Fig. 6 shows a large installation of gas-driven blowing engines built by Messrs. Richardsons, Westgarth & Co., Ltd, of Middlesbrough, for the Cargo Fleet Iron Co., Ltd. There are seven engines, of a total of 5,600 indicated h.-p.

Fig. 7 shows Messrs. Richardsons, Westgarth & Co.'s latest type of tandem double-acting gas-engines for dynamo and general work, and is shown as illustrating the latest development in this type of engine; the arrangement being one which, with alteration in detail, has been adopted generally by all the principal makers of gas-engines working on the "Otto" cycle.

It is thought that any notes upon large gas-engines in Great Britain should be accompanied by a reference to gas-cleaning, this being such an important

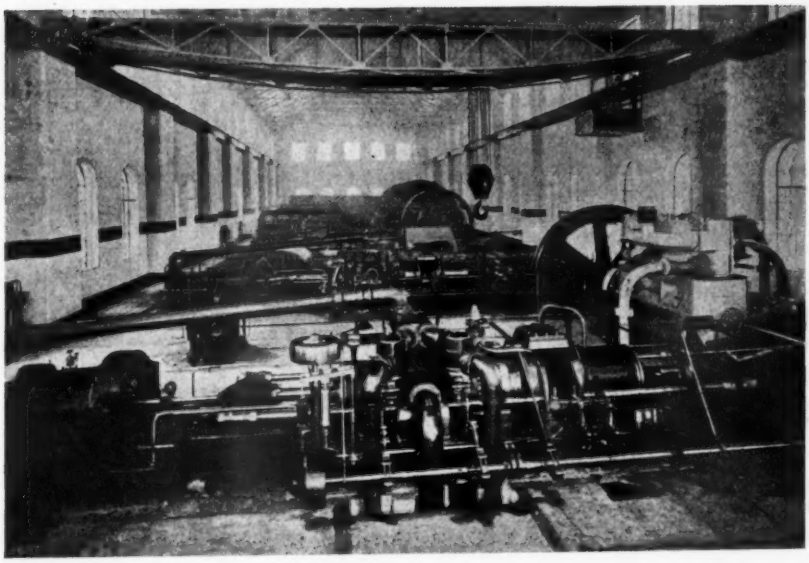
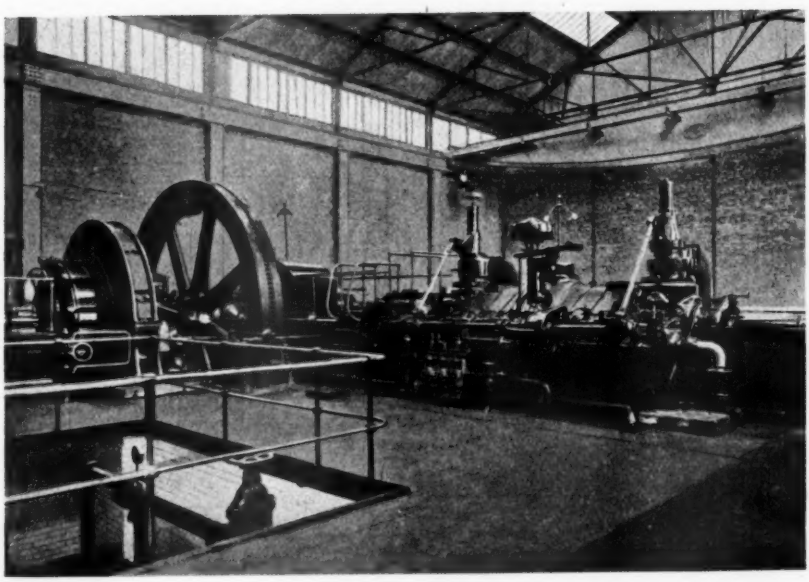


FIG. 1.



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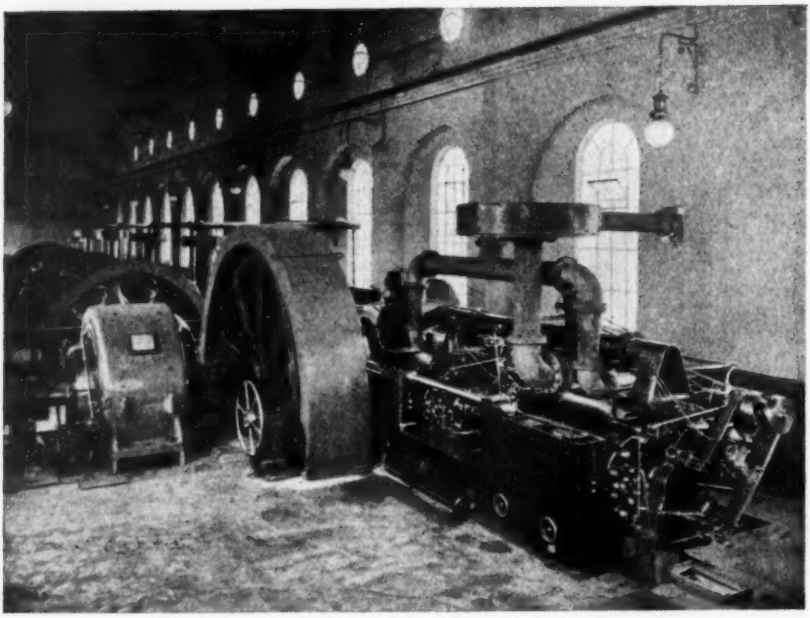


FIG. 3.

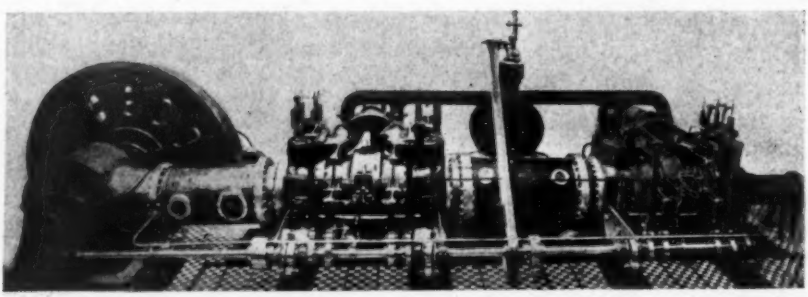
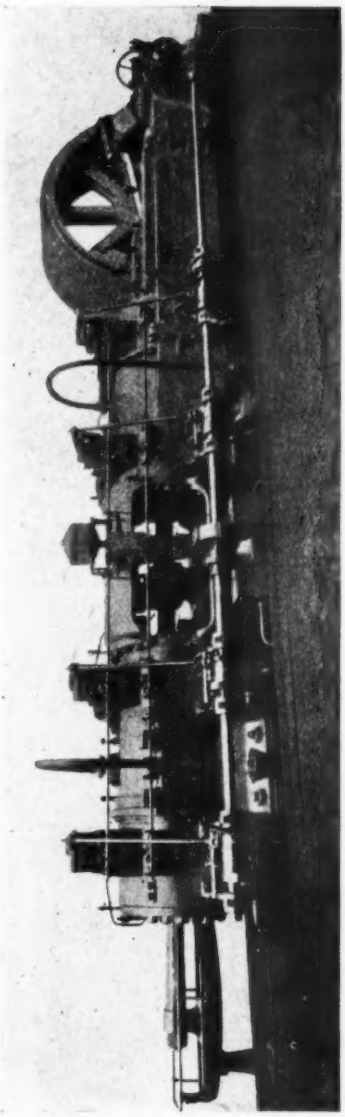


FIG. 4.



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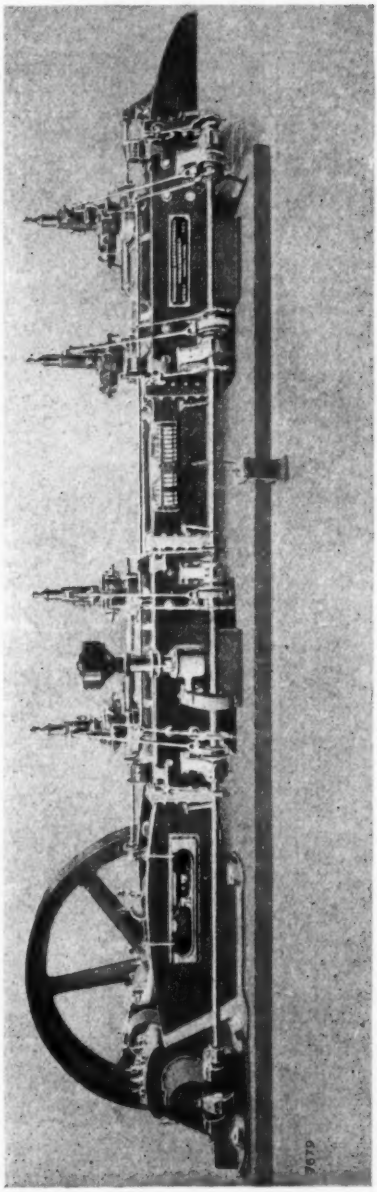


FIG. 7.

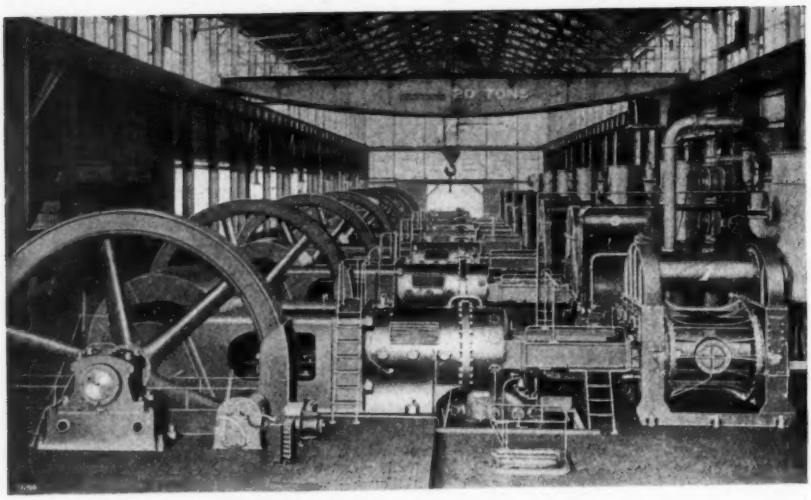



FIG. 6.

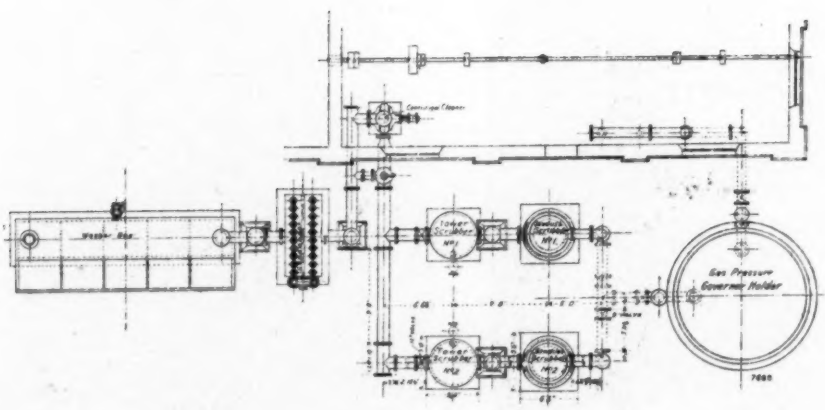



FIG. 8.

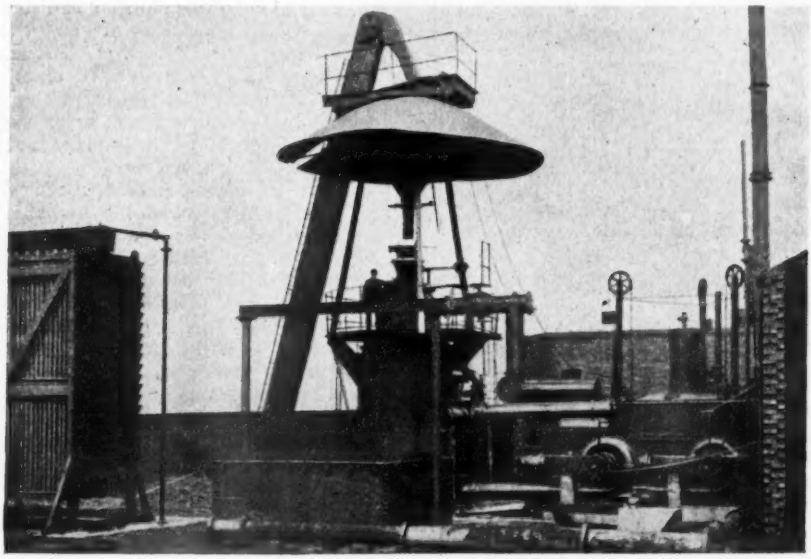


FIG. 9.

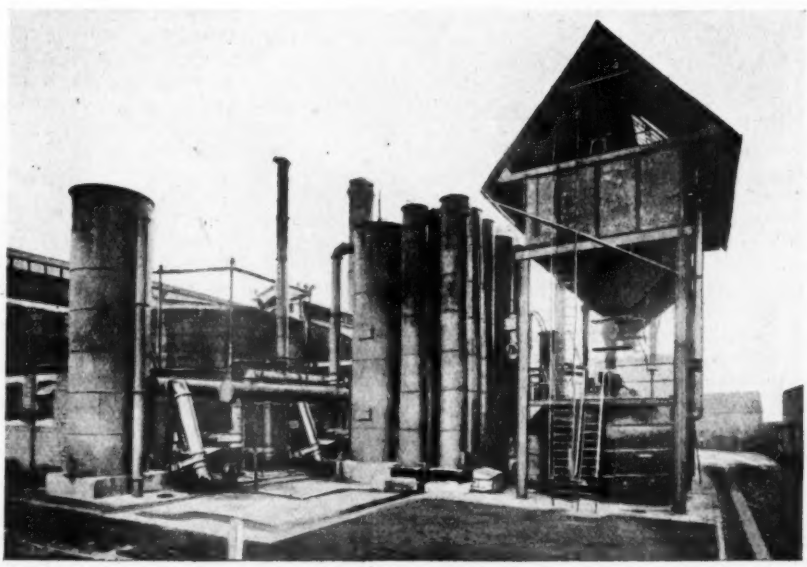


FIG. 10.

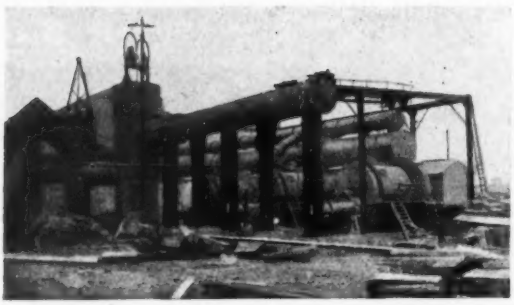


FIG. 11.

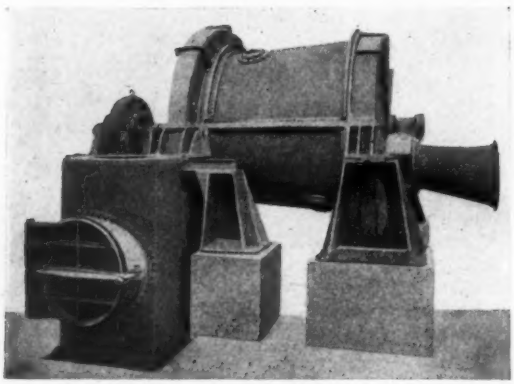


FIG. 12.

matter in connection with the proper running of the engines.

Most engineers commenced cleaning the gas for engines by passing it through ordinary fans with water. It was soon found that two or more fans in series would be necessary, and that a considerable quantity of water and much power was required, the result not always being satisfactory, particularly if the gas had not previously been very well cleaned and cooled by passing through large dust-catchers and long mains. A difficulty also occurs with the moisture absorbed by the gas in the fans, and it has been found necessary to supplement the fans by various cleaning and drying devices.

One of the pioneers in dealing with the cleaning of gas for engines was Mr. B. H. Thwaite, and Fig. 8 gives particulars of his apparatus, which is cleaning blast-furnace gas at Sheepbridge. A similar plant is also working at Ardsley.

Other methods of cleaning the gas upon much the same lines have been worked out in connection with producer gas by The Power Gas Corporation of Westminster, and Mason's Gas Power Co., Ltd., of Manchester. Fig. 9 shows one of the Power Gas Corporation's installations erected at West Gorton, and Fig. 10 a plant erected by Mason's Company at Reading. It will be observed that in both cases fans are used in conjunction with cooling towers, &c.

Figs. 11 and 12 represent a large installation of Theisen's Patent Gas-cleaning Apparatus, erected at the Cargo Fleet Company's works by Richardsons, Westgarth & Co., Ltd., of Middlesbrough, which shows the latest practice in cleaning blast-furnace gas. This apparatus is able to clean ordinary blast-furnace gas down to 0·002 grams per cubic metre with the use of less than one litre of water per cubic metre of gas. It will be observed that a vapour separating apparatus is fitted to the outlet of the Theisen cleaner, which has the effect of thoroughly drying the gas.

I have not entered into any detailed description of the various gas-cleaning apparatus named above, my object in these notes being merely to call attention to the various systems for the use of those who require general information. Nor have I made any mention of Zschocke, Bian, or Sahlin gas-cleaning plants, because, although these are receiving some attention in this country, they have not been used here so far as I know.

# The Structure of Metals.*

*By J. A. EWING, LL.D., F.R.S., M.Inst.C.E.*

I INTEND to devote this address to considering in certain aspects the inner structure of metals and the manner in which they yield under strain. It will not be disputed that this is a primary concern of the engineer, who in all his problems of design is confronted by the limitations imposed on him by the strength and elasticity of the materials he employs. It is a leading aim with him to secure lightness and cheapness by giving to the parts such dimensions as are no larger than will secure safety, and hence it is of the first importance to know in each particular case how high a stress may be applied without risk of rupture or of permanent alteration in form. Again, the engineer recognises the merit, for structural purposes, of plasticity as well as strength, and in many of his operations he makes direct use of that property, as in the drawing of wires and tubes or the flanging of plates. He is concerned, too, with the hardening effect that occurs in such processes when work is expended on permanently deforming a metal in the cold state, and also with the restoration to the normal condition of comparative softness which can be brought about by annealing. Nor can he afford to be indifferent to the phenomena of "fatigue" in metals, which manifest themselves when a piece is subjected to repeated alterations or variations of stress—fatigue of strength and fatigue of elasticity, which, like physiological fatigue, admits, under some conditions, of rest cure, inasmuch as it tends to disappear with the lapse of time. No apology need be made in selecting for a presidential address to Section G a subject that touches so many points of direct practical interest to engineers. It is a subject which has for me the additional attraction of lying in the borderland between engineering and physics—a borderland in which I have often strayed, and still love to stray, and I enter it to-day even at the risk of wandering into regions which, to engineers, may seem a little remote from home—regions where the landscape has, perhaps, a suspicious likeness to that of the country over which the learned men of Section A hold rule.

To engineers, quite as much as to physicists and chemists, we owe in recent years an immense extension of knowledge regarding the structure of metals. This has come about mainly by the intelligent use of the microscope. Take any piece of metal, in the state in which an engineer makes use of it, polish and lightly etch its surface, and examine it under the microscope, and you find that it is a congerie of a multitude of grains, every one of which may be proved to be a crystal. It is true that the boundaries of each grain have none of the characteristics of geometrical regularity which one is apt to look for in a crystal, but the grain is a true crystal for all that. Its boundaries have been determined by the accident of its growth in relation to the simultaneous growth of neighbouring grains — the grains have grown, crystal fashion, until they have met, and the surface of meeting, whatever shape it may happen to take, constitutes the boundary. But within each grain there is the true crystalline characteristic—a regular tactical formation of the little elements of which the crystal is built up. It is as if little fairy children had built the metal by piling brickbats in a nursery. Each child starts wherever it happens to be, placing its first brickbat at random, and then piling the others

* Address to the Engineering Section British Association.

side by side with the first in geometrical regularity of orientation until the pile, or the branches it shoots out, meets the advancing pile of a neighbour; and so the structure goes on, until the whole space is entirely filled by a solid mass containing as many grains as there have been nuclei from which the growth began.

We now know that this process of crystal growth occurs not only in the solidification of a metal from the liquid state, but in many cases during cooling through a "critical" temperature when the metal is already solid. We know also that the process may in certain conditions go on slowly at very moderate temperatures. We know also that the process of annealing is essentially the raising of the metal to a temperature at which recrystallisation may take place, though the metal remains solid while this internal rearrangement of its particles goes on. Whether crystallisation occurs in solidifying from the liquid or during the cooling of an already solid piece, it results in the formation of an aggregate of grains, each one of which is a true crystal. Their size may be large or small in general, quick cooling means that crystallisation starts from many nuclei, and the resulting grains are consequently small; with very slow cooling you get a gross structure made up of grains of a much larger size.

For simplicity of statement I shall ask you in what follows to confine your attention to simple metals, omitting any reference to alloys. Alloys present many complexities, into which we need not at present enter. With simple metals every crystalline grain is made of the same substance: the elementary brickbats are all exactly alike, though there may be the widest variation from grain to grain as regards the form of the grain, and also as regards the direction in which the elementary brickbats are piled. In any one grain they are piled with perfect regularity, all facing one way, like a regiment of perfectly similar soldiers formed up in rows where each man is equi-distant from his neighbours, before and behind, as well as to right and left.

Or, perhaps, I might compare them to the well-drilled flowers of an early Victorian wall paper.

It was shown by Mr. Rosenhain and myself that when a piece of metal is strained beyond its limit of elasticity, so that permanent set is produced, the yielding takes place by means of slips between one and another portion of each crystal grain. A part of each crystal slides over another part of the same crystal, as you might slide the cards in a pack. It is as if all the soldiers to one side of a given line were to take a step forward, those on the other side remaining as they were, or as if all the men in the front rows took a step to the left, while those in the rows behind kept their places. In other words, the plasticity which a metal possesses is due to the possibility of shear on certain planes in the crystal that are called "cleavage" or "gliding" planes. Plastic yielding is due to the occurrence of this shear. It may take place in three or more directions in a single grain, corresponding to the various possible planes of cleavage, and in each direction it may happen on few or many parallel planes, according to the extent of the strain to which the piece is subjected. Examine under the microscope the polished surface of a piece of metal which has been somewhat severely strained after polishing, and you find that the occurrence of this shear or slip is manifested on the polished surface by the appearance of little steps, which show themselves as lines or narrow bands when looked at from above. To these we give the name of slip-bands. Just as the piece of metal is an aggregate of crystal grains, the change of shape which is imposed upon it in straining is an aggregate effect of the multitude of little slips which occur in the grains of which it is made up. Each grain, of course, alters its form in the process.

Speaking broadly, this distortion of the form of any one grain by means of slips leaves it still a crystal. If part of the group of brickbats moves forward,

keeping parallel to themselves and to the others, the formation remains regular, except that a step is formed on the outermost rows; the orientation of the elements continues the same throughout. Considerations which I shall mention presently lead to some qualification of this statement. I now see reason to believe that in the process of slip there is a disturbance of the elementary portions or brickbats adjoining the plane of slip, which may alter their setting, and thereby introduce to a small extent some local departure from the perfectly homogeneous orientation which is the characteristic of the true crystal. In very severe straining there may even be a wide departure from true crystalline character. We shall recur to this later; but meanwhile it will suffice to say that substantially the slip which is involved in a plastic strain of moderate amount is a bodily translation, parallel to themselves, a part of the group of elementary brickbats or molecules which build up the grain. If a crystal whose form has been altered, even largely, by such straining is cut and polished and etched it appears, under the microscope, to be to all intents and purposes as regular in the tactical grouping of its elements as any other crystal.

Further, in the process of straining we have, first, an elastic stage, extending through very small movements, in which there is no dissipation of energy and no permanent set. When this is exceeded, the slip occurs suddenly; the work done in straining is dissipated; if the straining force is removed, a strain persists, forming a permanent "set"; if it continues to act, it goes on (within certain limits) producing augmented strain.

In general, a large amount of strain may take place without the cohesion between the gliding surfaces being destroyed. Immediately after the strain has occurred there is a marked fatigue, showing itself in a loss of perfect elasticity; but this will disappear with the lapse of time, and the piece will then be harder than at first. If, on the other hand, a process of alternate straining back and forth be many times repeated, the piece breaks. These are now familiar facts. Can we attempt to explain them on the basis of a molecular theory which will, at the same time, offer a clue to the process of crystal-building as we find it in metals? I venture to make this address the occasion of inviting attention to some more or less speculative considerations which may be held to go some little way towards furnishing the material for such an explanation.

At the Leeds meeting of this association, in 1890, it was my privilege to bring forward certain contributions to the molecular theory of magnetism, and to show a model which demonstrated that the rather complex phenomena of magnetisation were explainable on the very simple assumption that the magnetic molecules are constrained by no other forces than those which they mutually exert on one another in consequence of their polarities. From this were found to result all the chief phenomena of permeability and magnetic hysteresis. Let us attempt to-day to apply considerations of a similar character to another group of physical facts—namely, those that are associated with the crystalline structure of metals and with the manner of their yielding under strain. Just as in dealing with magnetic phenomena, I take as a starting point the idea that the stability of the structure is due to mutual forces exerted on one another by its elementary parts or molecules, and that the clue to the phenomena is to be sought in the play of these mutual forces when displacement of the molecules occurs.

Iron and most of the useful metals crystallise in the cubic system; for simplicity we may limit what has to be said to them. Imagine a molecule possessing polarity equally in three directions, defined by rectangular axes. We need not for the present purpose inquire to what the polarity along the axes is due; it will suffice to assume that the molecule has six poles, three positive and three negative, and that these repel the like and attract the

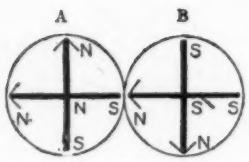



FIG. 1.

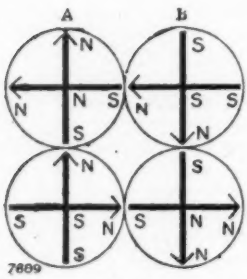



FIG. 2.

unlike poles of other molecules. We may make a model by using three magnetised rods fixed at right angles to one another at their middle points. I imagine, further, that the molecule has an envelope in the shape of a sphere, which touches the spherical envelopes of its neighbours, and assume that these spheres may turn on one another without friction. Or, let the envelope be a shell of any form, inside of which the axes of polarity are free to turn as a rigid system.

Think now of the process of crystal-building with a supply of such spherical molecules for brickbats. Starting with one molecule, let a second be brought up to it and allowed to take up its place under the action of the polar forces. It will have a position of stability when a positive pole in molecule *A* touches, or lies in juxtaposition to, a negative pole in molecule *B*, with the corresponding axes in line, and when the further condition is satisfied that the axes in molecule *B*, whose poles are not touched by *A*, are stably situated with respect to the field of force exerted by the poles of *A*. In other words, we have the formation shown in Fig. 1. For convenience of representation in the diagram the poles are distinguished by the letters *N* and *S*, but it must not be assumed that the polarities with which we are here concerned have anything to do with magnetism. Suppose, now, that the crystal is built up by the arrival of other molecules, each of which in its turn assumes the position of maximum stability consistent with formation in cubic or normal piling. The group in that case takes an arrangement which is essentially a repetition of this quartette (Fig. 2). Along each row the polarity preserves the same direction, but the polarity of each row is opposite to that of each contiguous parallel row. This description applies equally to all three axes. The whole group (Fig. 3) consists of the quartettes of Fig. 2 piled alongside of and also on top of one another. In this way we arrive at what I take to be the simplest possible type of cubic crystal. In this grouping each molecule has the alignment giving

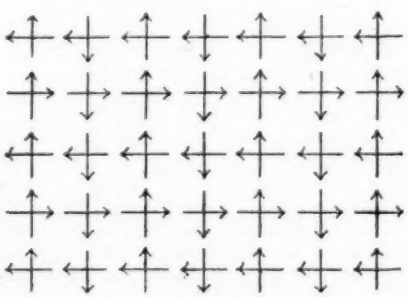


FIG. 3.

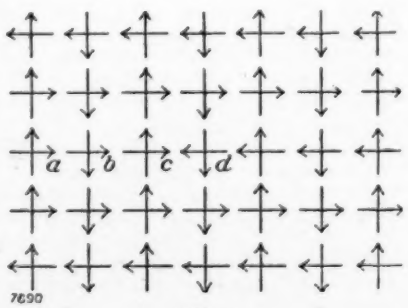



FIG. 4.

maximum stability, and it seems fair to assume that it will take that alignment when the crystal grain is formed under conditions of complete freedom, as in solidifying from the liquid state. As a rule the actual process of crystal building goes on dendritically; branches shoot out, and from them other branches proceed at right angles, leaving interstices to be filled in later. We have, therefore, to conceive of the molecules as piling themselves perferably in rows rather than in blocks, though ultimately the block form is arrived at. In this position of maximum stability each molecule has its six poles touching poles of contrary name.

Now comes a point of particular importance. Imagine two neighbouring molecules in the same block to be turned round, each through one right angle, in opposite senses. They will now each have five poles touching five poles of contrary name, but the sixth pole will touch a pole of the same name as itself. They are still stably situated, but much less stably than in the original configuration, and they will revert to that configuration if set swinging through an angle sufficient to exceed the limited range within which they are stable in the new position. Similarly we may imagine a group of three, four, or more molecules, each to be turned through a right angle, thereby constituting a small group with more or less stability, but always with less than would be found if the normal configuration had been preserved. The little group in question may be made up of molecules in a row, or it may be a quartette or block, or take such form as a *T* or *L*. A sufficient disturbance tends to resolve it into agreement with the normal tactics of the molecules which build up the rest of the grain. It is conjecturally possible that small groups of this kind, possessing little stability, may be formed during the process of crystallisation, so that here and there in the grain we may have a tiny patch of dissenters keeping one another in countenance, but out of complete harmony with their environment. If this happens at all during crystallisation, it would seem less likely to happen in free crystallisation from a liquid state than in the more constrained process that occurs when a metal already in the solid state recrystallises at a temperature far below its melting point. Though rare or absent in the first case, it might occur frequently in the second. There are differences in the appearance of crystal grains under the microscope in metal as cast and in metal as recrystallised in the solid state, of which this may be the explanation. It may also explain a difference pointed out by Rosenhain, that the slip lines in cast metal are straight and regular, whereas in wrought iron and other metals which have recrystallised in the solid they rarely take a straight course across the crystal, but proceed in jagged, irregular steps. These may be due to the presence here and there of small panes of weakness, resulting from the existence of what I have called dissenting groups. Again, these groups possessing as they do less stability than their normal neighbours, may be conjectured to differ from the normal parts of the grain in respect of electrolytic quality, and to be more readily attached by an etching reagent. Hence, perhaps, the conspicuous isolated geometrical pits that appear on etching a polished surface of wrought iron.

It will help in making clear these points and others that are to follow, if we study the action of a model formed by grouping a number of polarised "molecules" in one plate, supporting them on fixed centres about which they are free to turn. In the model before you the centres are uniformly spaced in rectangular rows, and the "molecules" are + -shaped pieces of hardened steel, strongly magnetised along each of the crossed axes, each having, therefore, two north poles and two south poles. The third axis is omitted in the model, the movement to be studied with the help of the model being movement in one plane. On placing these "molecules" on their centres they readily take up the position already indicated in Fig. 3. Each one

within the group has its four poles in close proximity to four poles of contrary name, and is, therefore, highly stable. If disturbed by being turned through a small angle, and let go, it swings back, transmitting a wave of vibration through the group, which is reflected from the edges, and is finally damped out in the model by pivot friction and air friction. We may assume some damping action (say by the induction of eddy currents) in the actual solid, of which the model may be taken as a very crude representation. By turning two molecules carefully round together, each through one right angle in opposite senses, we set up a dissenting pair, whose equilibrium has feeble stability. A slight displacement, such as might by produced by the transmission of a vibrational wave, breaks them up, and they swing back to the normal configuration, giving out energy, which is taken up by the rest and is ultimately dissipated. By making the dissenting coterie consist of three or more we can give it additional strength. An example is shown in Fig. 4, where the three molecules, marked *a*, *b*, and *c*, are turned round in this way. Notice that the normal molecule *d*, adjoining a line of such dissenters, is in a peculiar position. His neighbours present to him three *N* poles and one *S* pole. He has the choice of conforming to the majority, or of throwing in his lot with the dissenters; and he has a third possible position of equilibrium (very feeble equilibrium) which is reached when his two *S* poles are turned until the one neighbouring south pole faces just betwen them. I have laboured these points a little because they seem important when we come to speak of the effects of strain.

Consider now the straining action, which we may imitate in the model by sliding one part of the group past the other part. For this purpose the centres are cemented to two glass plates, which can slide parallel to one of the axes. At first, when the displacement by sliding is exceedingly small, the strain is a purely elastic one. The molecules adjacent to the plane of sliding pull one another round a little, but without breaking bonds, and if in this stage the strain is removed by letting the plate slide back to its original position, there is no dissipation of energy. The work done in displacing molecules is recovered in the return movement. We have here a representation of what happens between each pair of adjoining rows in the elastic straining of a metal. So far the action is within the limit of elasticity; it leaves no permanent effect; it is completely reversible. But now let the process of straining be carried further. The opposing molecules try to preserve their rows intact, but a stage is reached when their resistance is overcome; the bonds are broken, and they swing back, unable to exert further opposition to the slip. The limit of elasticity has now been passed. Energy is dissipated; set has been produced; the action is now no longer reversible. The model shows well the general disturbance that is set up in the molecules adjoining the plane of slip, which we may take to account for the work that is expended in a metal in producing plastic strain. Moreover, when the slip on any plane stops and the molecules settle down again, the chances are much against their all taking up the normal orientation which they had before the disturbance. What I have called dissenting groups or unstable coteries are formed as a result of the disturbance. Here and there like poles are found in juxtaposition. Viewed as a whole, the molecular constitution of the metal in the region adjacent to the plane of slip is now uncertain and patchy. It includes parts whose stability is much less than normal. Individual molecules or small groups in it are very feebly stable; a touch would make them tumble into positions of greater stability. Observe how all this agrees with what we know about the nature of plastic strain through experiments on iron or other metals. Its beginning is characteristically jerky. Once the critical force is reached, which is enough to start it, there is a big yield, which will not be stopped even by reducing the amount of the straining force.

Again, we know that there is a slow creeping action that continues after the straining force has done its main work. I ascribe this to the gradual breaking up of the more unstable groups which have been formed during the subsidence of disturbance in the earlier stage of the slip. Further, we know that over-strained iron is very imperfectly elastic until it has had a long rest, or until it has been raised for a short time to a temperature such as that of boiling water. This is to be expected when we recognise the presence of unstable individuals or groups resulting from the overstrain. When the elasticity of the overstrained piece is tested by removing and reapplying the load, some of these tumble into new positions, making inversible movements, which dissipate energy and produce hysteresis in the relation of the strain to the stress although the strain is quasi-elastic. At ordinary temperatures these unstable groups are gradually becoming resolved, no doubt through the action of the molecular movements that are associated with heat, and hence the slow progressive recovery of perfect, or nearly perfect, elasticity shown by the experiments of Muir. Let the temperature be raised and they disappear much more quickly; in warm surroundings the rest-cure for elastic fatigue does not need to be nearly so long. Rosenhain has recently shown that after the slipbands on the surface of an overstrained specimen have been obliterated by polishing, traces of them will reappear on etching if only a short interval of time is allowed to lapse since the overstraining; but if time is given for complete recovery no traces are found. This is in remarkable agreement with the view now put forward, that the layers contiguous to the service of slip contain for a time comparatively unstable groups. They are consequently different from the normal metal until the unstable groups are resolved, and the temporary difference manifests itself on etching, provided that is done while the difference still exists.

From the engineer's point of view, a much more important matter than this fatigue of elasticity is the fatigue of strength that causes fracture when a straining action is very frequently repeated. Experiments which I made with Mr. Humfrey showed that this action begins with nothing more or less than slight slip on surfaces where the strain is locally sufficient to exceed the limit of elasticity. An alternating stress, which makes the surfaces slip backwards and forwards many thousands, or it may be millions, of times alternately, produces an effect which is seen on the polished surface as a development of the slip lines into actual cracks, and this soon leads to rupture. We have, therefore, to look for an effect equivalent to an interruption of continuity across part or the whole of a surface of slip, an effect progressive in its character, becoming important after a few rubbings to and fro if the movement is violent, but only after very many rubbings if the movement is slight. That there is a progressive action which spreads more less into the substance of grain on each side of the original surface of slip was clearly seen in the experiments referred to. It was found that a slip-band visible on the polished suface of the piece broadened out from a sharply defined line into a comparatively wide band with hazy edges, and this was traced to an actual heaping up of material on each side of the step which constituted the original line. I think this suggests that under alternating stresses which cause repeated backward and forward slips, these do not occur strictly on the same surface in the successive repetitions, and hence the disturbance extends to some extent laterally. It may be conjectured that slip on any surface leaves a more or less defective alignment of the molecular centres—that is to say, the rows on one side of the plane of slip cease to lie strictly in line with those on the other side. If this occurs over neighbouring surfaces, as a result of slips or a number of parallel planes very close together, the metal throughout the affected region loses its strictly crystalline character,

and with it loses the cohesion which is due to strict alignment.

Mr. G. T. Beilby, in a very suggestive paper, has advanced grounds for believing that portions of a metal may pass from a crystalline to an amorphous formation under the mechanical influence of severe strain, as in the hammering of gold leaf or the drawing of wire, and that this occurs in the polishing of a metallic surface, and also in the internal rubbing which takes place at a surface of slip within the grain. In both cases he suggests the formation of an altered layer. When a polished metal surface is etched, the altered layer is dissolved away, and the normal structure below it is revealed. Without accepting all Mr. Beilby's conclusions, I think the idea of an altered and more or less amorphous layer is supported by the considerations I am now putting forward. We have assumed that in normal crystallisation the intermolecular forces lead to a normal piling, in which each molecule touches six neighbours. But it may be conjectured that some of them may take up pyramid piling (touching twelve others) under the compulsion of strong forces—such forces, for example, as act on the superficial molecules of a surface that is being polished. If this also occurs at a surface of slip, it gives us a clue to several known facts. It at least assists in explaining the familiar result that metal is hardened by straining in the sense of being made less plastic. Again, it accounts for the general increase of density which is found to take place in such an operation as wire drawing. Further, if a local increase of density occurs in the interior of a grain through piling of some molecules in the closer manner where repeated slips are going on, the concentration of material at one place requires it to be taken from another; in other words, the closer piling tends to produce a gap or crack in the neighbourhood where it occurs. This is consistent with what we know of the development of cracks through repeated alterations of strain.

Recourse to the model shows that with pyramidal piling the polar axes point in so random a manner that the aggregate may fairly be called amorphous. To illustrate this a group is shown with centres fixed at the corners of equilateral triangles. It is obvious that any pyramidal piling at a surface of slip tends to bar further slip at that particular surface. Hence not only the augmented hardness due to strain, but the tendency in repeated alterations to lateral spreading of the region on which slip occurs. The hardness due to straining is, of course, removed when we raise the metal to such a temperature that complete recrystallisation occurs, normal piling then being restored in the new grains. Taking a previously untrained piece, it is clear that the faculty with which slip will occur at any particular surface of slip in any particular grain depends not only on the nature of the metal and on the orientation of the surface in question to the direction of the stress, but also on the amount of support the grain receives from its neighbours in resisting slip there. In others words, for a given orientation of surface the resistance to slip may be said to consist of two parts; one is inherent in the surface itself and the other is derived from the position of the grain with reference to other grains. To make this point clear, think of a grain (under stress) in which there is a gliding surface oriented in the most favourable direction for slipping. Slip on this surface can take place only when its yielding compels the neighbours (which are also under stress) to yield with it, and the surfaces in these on which slip is compelled to occur are, on the whole, less favourably situated. Hence the original grain cannot yield until the stress is considerably in excess of that which would suffice to make it yield if it stood alone, or had neighbours equally favourably inclined.

Apply this consideration to the case of steel, where there are two classes of grains: the ferrite, which is simply iron, and the pearlite, which is a harder structure. Slip on any ferrite grain is

resisted partly by the strength of the surface itself and partly by the impossibility of its yielding without forcing slip to take place on neighbouring (harder) grains. Now suppose the structure is a very gross one, such as Mr. Stead has shown may be found in steel that is seriously overheated. On the large grains of ferric in overheated steel the resistance to slip will be but little greater than it would be in iron, and, consequently, under an alternating stress fatigue of strength, leading to rupture, may be produced by a very moderate amount of load. Mr. Stead has shown how the effects of overheating can be removed by the simple expedient of raising the steel to a temperature sufficient to cause recrystallisation—a homœopathic remedy that transforms the gross structure of the overheated metal into an ordinarily fine structure, where no ferrite grain can yield without compelling the yielding of many pearlite grains. Hence, we find, as Rogers has demonstrated by experiment, that steel cured by reheating from the grossness of structure previously produced by overheating, has an immensely increased power to resist the deteriorating effects of often repeated stress.

I trust you will not feel I have abused the licence of the chair in presenting contributions to molecular theory that are for the most part in the nature of speculative suggestions, thrown out in the hope that they may some time lead to fuller and more definite knowledge. Remote as they may seem to be from the concerns of the workaday engineer, they relate to the matter which it is his business to handle, and to the rationale of properties, without which that matter would be useless to serve him. We have attempted to penetrate into its very heart and substance in order the better to comprehend the qualities and functions on which the practical work of engineering relies. The man whose daily business leads him through familiar tracks in a forest does well to stray from time to time into the shady depths that lie on either hand. The eyes of his imagination will be opened. He will at least learn his own limitations, and, if he is fortunate, he may gain some clearing on a hilltop which commands a wider view than he has ever had before.

# Automobile Engineering.

*By ROBERT E. PHILLIPS, M.I.Mech.E., A.M.Inst.C.E.*

**Motor Lifeboat.**—The Royal National Lifeboat Institution, being fully alive to the advantages of mechanical propulsion for their craft, have recently had one of their boats, the *Michael Henry*, fitted with a 4-cylinder 24 h.-p. "Thornycroft" motor, as an auxiliary, with excellent results. At the trials carried out in the Thames an average speed of just over 7 knots an hour was maintained by means of the motor only, with the boat fully equipped and with ballast equivalent to the weight of a full crew. The engine is so encased as to be perfectly watertight, and it is so arranged that it will automatically stop running when the boat is keel uppermost, and thus prevent possible injury to anyone coming into contact with the revolving screw. During the trials the boat was repeatedly capsized, and each time the motor stopped running when the boat assumed a certain inclined position, and the casing of the engine proved perfectly watertight at every point, which is saying a good deal, having regard to the fact that all the pipes and control rods have to pass through packed glands.

**A Combined Road Sweeper and Watering Cart.**—A useful form of combined mechanical road-sweeper and watering cart has been produced by Messrs. D. Stewart & Co., Ltd., of Glasgow. It consists of a standard 4-ton 30 h.-p. "Stewart-Thornycroft" steam chassis, which carries over the rear wheel a cylindrical tank of 1,000 gals. capacity, which is provided with two outlets, fitted with circular valves controlled from the driver's platform, the outlets being connected by means of armoured hose, with two sprinklers located on either side of the forward part of the chassis. The sprinklers are each divided into two compartments of unequal size, each of which is controlled by a separate valve so that either or both may be used as required. The brush is carried in a frame at the rear of the vehicle, behind the rear driving wheels, and is driven by the motor by means of a lay shaft and bevel gearing, a clutch being interposed between the engine shaft and the lay shaft to enable the brush to be started and stopped as required. The frame carrying the brush is raised or lowered by means of a wire rope operated by a small winch on the driver's platform. One of these machines has been used by the Glasgow Corporation for some time, and is found to do the work—either watering or sweeping—of three horse-drawn appliances.

**The "Sentinel" Steam Wagon.**—This steam wagon, which is manufactured by Messrs. Alley and MacLellan, of Polmadie, Glasgow, differs from most other steam wagons, inasmuch as it has a slow-speed engine driving the axle carrying the driving wheels direct, without the intervention of any change speed gear. Such a combination is not only much simpler and less liable to give trouble on the road than a high-speed engine with a change-speed gear, but it comes out considerably lighter. The saving effected in wear and tear of the parts is too obvious to need commendation.

The engine, which develops 20 to 40 h.-p. economically, and will develop 70 h.-p. when required, is of the two-cylinder simple type. The proportions are ample throughout, and the bearings, which are in an oil bath, run for long periods without adjustment. The valves are of the poppet type, so that they can be ground into their seats when worn. Separate valves are employed for the admission and exhaust of the steam. These are placed below the cylinders at each end, and are operated by a cam shaft, which runs in the oil-tight box lying transversely below the cylinders. The control lever moves this cam shaft axially, and brings into action the various sets of cams which cause the engine to go ahead or reverse as required. By the separation of the admission and exhaust, the steam distribution can be regulated to the best advantage, thus obtaining the greatest economical ranges of power. It will be seen that any moisture in the cylinders at once falls out through the exhaust valves, thus enabling the usual drain taps to be dispensed with. As the steam and exhaust valves are separate, live steam cannot leak to the exhaust without passing both valves. The bearings are all of very ample surface, the normal pressure being from 100 lbs. to 300 lbs. per

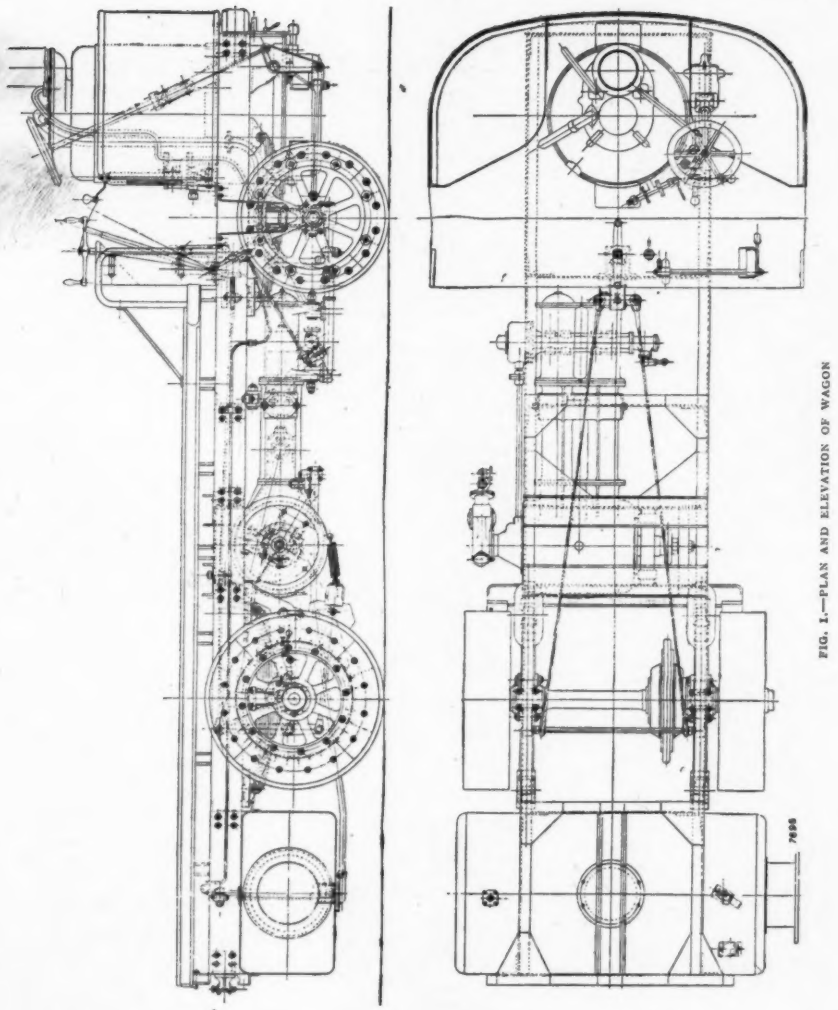


FIG. 1.—PLAN AND ELEVATION OF WAGON

square inch. Not only is dust carefully excluded, but as the bearings run continuously flooded with oil, their life is greatly increased. Access can readily be had to all parts by means of large doors.

The boiler, which is cylindrical in form, has no stays, and is amply strong for 250 lbs. working pressure. It is capable of evaporating 1,000 lbs. of steam per hour, against the 300 to 400 lbs. required in average actual work. The inside shell is cylindrical round the fire space, and above that it is pressed square to take the weldless steel cross-tubes, and above that again it is cylindrical to form the up-take. From the top, which forms the smoke box, depends the stoking shoot, between which and the inner shell is placed the steam drying coil. This coil is protected by the cross water tubes so that it cannot be burnt out when the wagon is

standing. Below the fire-grate is the water-tight ash-pan. It will be seen that the tube ends are all under water, and that the small crown is amply submerged and protected from the impact of the flame by the cross tubes. Owing to the small diameter of the boiler, tilting, as when going up or down a hill, does not expose the crown, and makes but small variation of water level in the gauge glass. By slacking off two rows of bolts the inner shell may be dropped down until it is fully exposed, as shown in the illustration, without uncoupling any of the connections to the outer shell. In this position its surfaces can be scaled and the tubes cleaned very easily. By moving the wagon backwards a man may stand up inside the outer shell and thus be able to clean and inspect it in comfort. The boiler is preferably fired with coke through the shoot

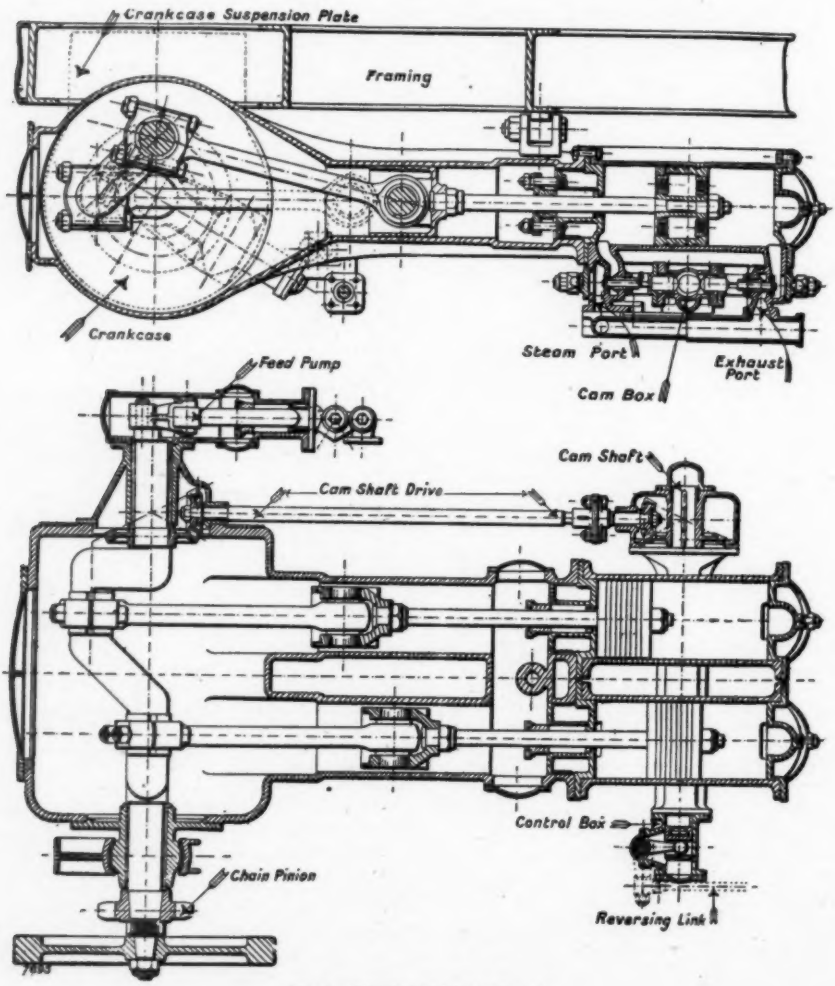



FIG. 2.—ENGINE FOR STEAM WAGON.

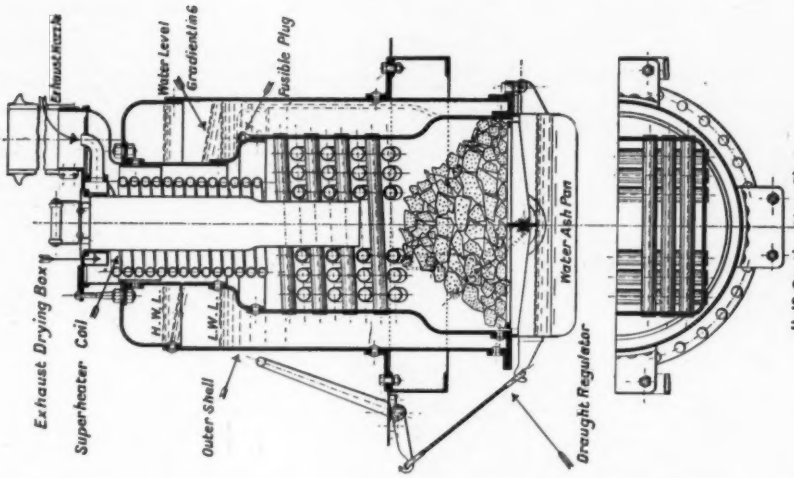



FIG. 4.—BOILER.

depending from the top. The grate holds 20 to 30 minutes' supply of fuel at the ordinary rate of consumption, and as combustion space is provided above the highest possible fire, it is practically impossible to choke the fire.

The transmission consists of only two sprocket wheels and a single chain. The differential gear, which is cased and runs in an oil bath, from which dust is excluded, has a locking gear which can be thrown into gear by pulling out a pin for use on greasy roads or going up hill. The single-chain drive has been adopted as the simplest and best form of transmission, after considerable experiment with other forms of gear. It allows for the rise and fall, while the inclined position of the axle and side play are provided for by a minute "give" in each of the many links of the chain.

The road wheels, as will be seen from the illustration, are of novel pattern, wherein stretch of the tyre is taken up by an annular ring, so that a tyre can be replaced cold by

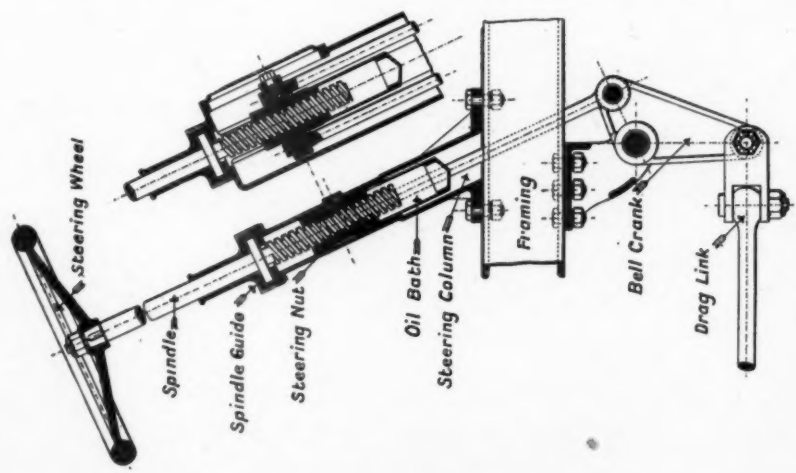



FIG. 3.—STEERING GEAR.

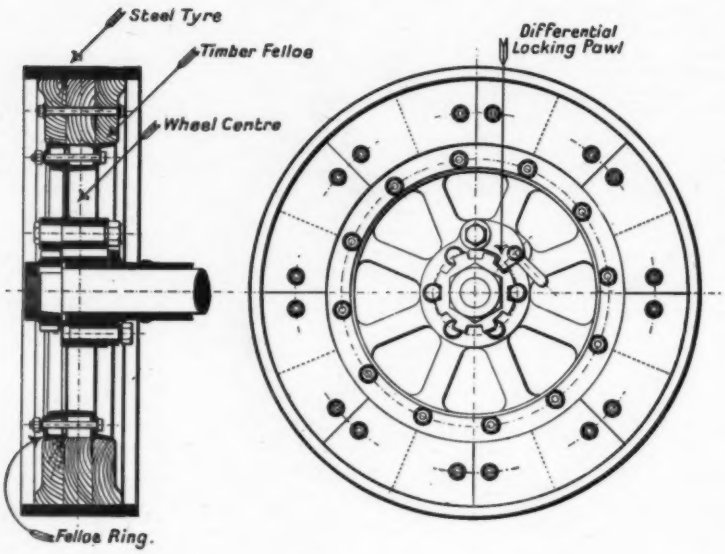



FIG. 5.—ROAD WHEEL DETAILS.

the driver without the use of an hydraulic press. The wheel consists of a steel centre, a wedge ring, a wood felloe ring, and a steel tyre. The felloe ring is internally coned from each side, and when the wedge ring is drawn towards that which is formed on the steel centre, the felloe is forced out against the tyre. The manufacturers claim the

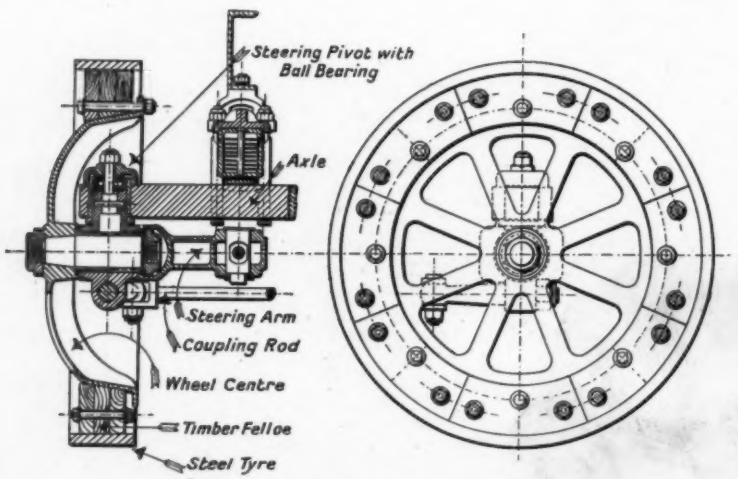



FIG. 6.—FRONT WHEEL. STEERING GEAR

following advantages for this construction:—

(1) The wheel, while lighter, is much stronger than any other pattern.

(2) The correct mechanical design of the wheel makes it much more durable than any other.

(3) The cushion given by wood felloes absorbs the smaller vibrations, prevents ringing, and conduces to durability and silence.

(4) The tyre may be properly fastened on in a mechanical way.

(5) Stretch of the tyre is easily followed up.

(6) Tyres may be readily renewed when worn out.

(7) In nearly all wheels the rim and tyre, being supported from spokes, are subjected to bending stresses, which greatly shorten their life. With this the double steel rim sandwiched on the wooden felloe is a mechanically strong and durable job.

(8) The felloes being built up of comparatively small pieces can be made of better quality timber.

(9) The pressure on the wood is distributed over five times the area it is concentrated on with the artillery pattern wheel, and crushing and working loose in obviated.

The steering gear is also of novel construction. As will be seen by the illustration, the front road wheels are dished so that the pivots or steering heads come in the centre of the wheels. The usual arms are fixed one on each steering pivot, and are coupled together by a rod, so that the wheels work in unison. An arm fixed to one of the pivots is operated by a hand wheel through the medium of a screw and nut, the latter being connected by means of a pair of links with a bell-crank lever connected by means of a drag-link with the said arm. It is claimed for this construction that:—

The bearings are truly loaded about their centres, and therefore wear very much longer than other types; hitting an obstacle throws no strain on the actual steering or hand gear; in the act of steering the wheels are swung on their centres and not traversed, thus reducing the power required; the gear is irreversible and can be made quick-acting without danger; the turning circle of the wagon may be made smaller.

The control gear is conveniently arranged so that the driver's hands fall right on to every handle in general use. The driver sitting in his place has before him the steering wheel, at his right hand the engine reverse lever, and at his left hand the throttle valve. These enable him to stop,

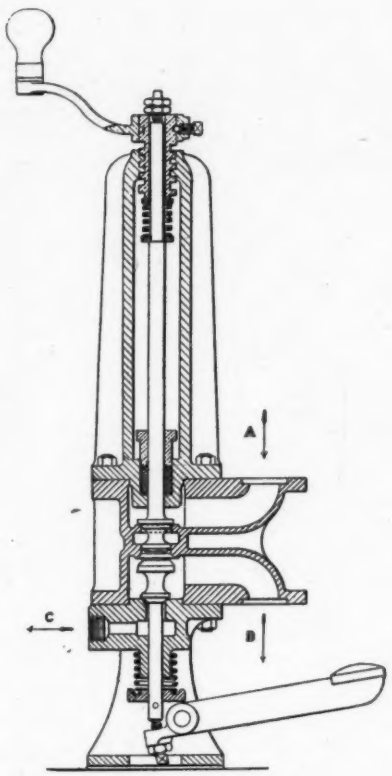
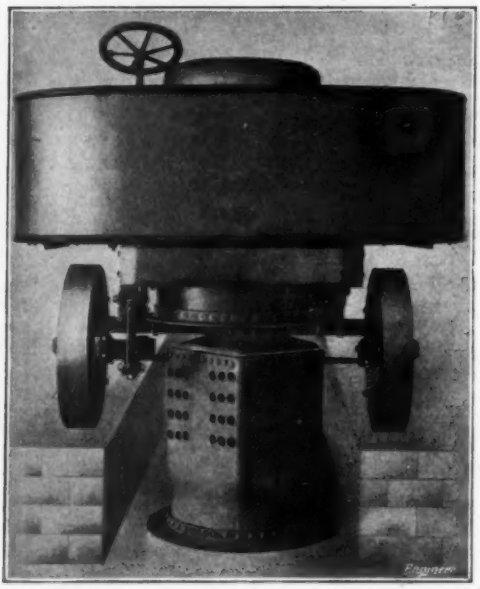



FIG. 7.—THROTTLE VALVE GEAR.

to start, to go ahead, or back quickly or slowly in any direction. For convenience in driving a foot lever is also provided for operating the throttle valve, which enables the driver to stop and restart the wagon by pressing down his foot without interfering with his other adjustments.

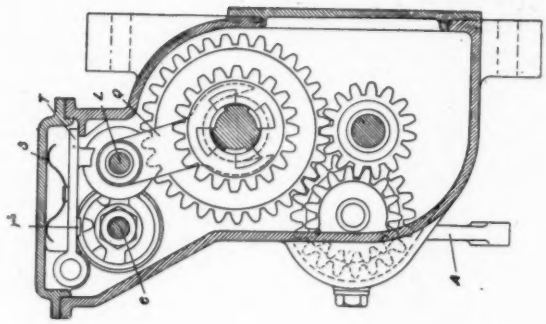
The makers claim, and we think justly so, that they have in their wagon reduced the work of the driver to a minimum, and state with confidence that after a day's practice a driver will with it manœuvre quicker, cover the ground quicker, and come in fresher after his day's work, and if he has got clear away he will have done a much bigger day's work than he could with any other mechanically propelled wagon.

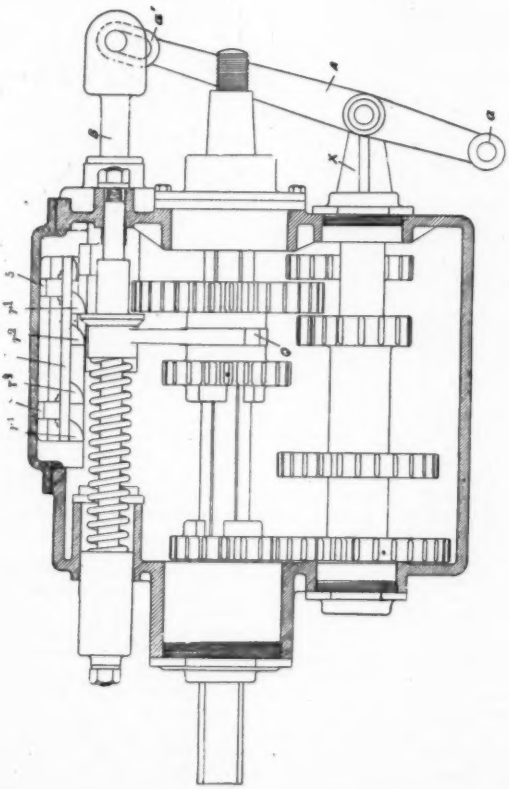
**An Automatic Change Speed Gear.**—The changing of gear in a motor car has always been a source of trouble to all but

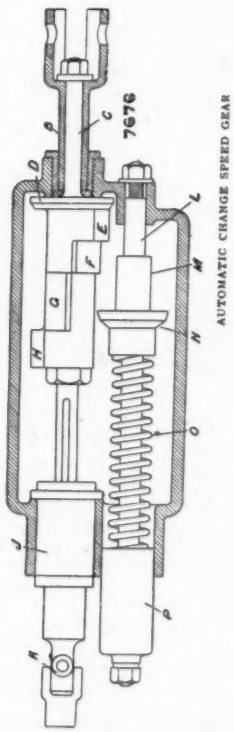


ILLUSTRATING THE EXPOSURE FOR CLEANING INSIDE SURFACES OF THE BOILER.

the most expert drivers, and as the "train balladeur" at present holds the field, any arrangement that will relieve a driver of the actual function of changing gears will come as a boon and blessing to men. Messrs. Scowen, Ltd., of Reading, are introducing a device for automatically changing the gear. The illustrations show an ordinary type of three forward speeds and reverse gear box, to which this device has been added. On to a bracket X, mounted on the gear box Y, is hinged a lever A, one end *a* of which is connected to the clutch pedal, and the other end *a* 1 to a longitudinally arranged hollow shaft B. Passing through the shaft B is a shaft C carrying a coned flange D and a series of teeth, E, F, G and H. The other end of the shaft C passes through a casing J, through which it is free to slide, but has no independent rotary movement by reason of the featherway. Outside the gear box is a universal joint K which is connected up by any suitable means to an indicating sector on the steering pillar. The whole of the mechanism on the shaft C, including the casing J, can be revolved to the right or left by the universal joint K, whilst the hollow shaft B, carrying with it shaft C, can be pushed over to the left by means of the lever A. Parallel with the shaft C is a second shaft L, upon which is loosely mounted a sleeve M carrying a coned flange N and a spring O, which abuts against the sleeve M and slides into the casing P when pushed home. To the sleeve M is attached the usual gear-changing fork Q. Above the two shafts C and L is a plate R, which is hinged on one side and normally rests at the other side on a small projection on the gear box. Above the plate R are two springs S which operate to keep the plate pressed down. On the underside of the plate R are four rack teeth, *r* 1, *r* 2, *r* 3 and *r* 4, which are in line with the coned flange N, and a small tooth *r* 5 in line with the shaft C. In the plan view the change-speed gear is shown in the neutral position. If it is desired to change to the first speed, the indicator on steering column is put over to the proper point on its sector, by which shaft C is revolved until the tooth F is pointing towards the shaft L. This movement can be effected at any time prior to the time it is desired to change the gear. The operation of de-clutching pushes the lever A over to the left, carrying with it hollow shaft B and shaft C, whereby the coned flange D comes in contact with the tooth *r* 5 upon the hinged plate R, and thereby lifts the said plate slightly. The front of tooth E as the shaft C moves to the left, comes against back of the coned flange N and pushes it also to the left against the pressure of the spring O. The movement of the coned flange N also helps to lift the locking plate R by means of its coned surface coming into contact with one of the teeth *r*. As the coned flange N is rigid with the fork Q, the latter is also carried forward, thereby bringing the gear wheels into mesh for the first speed. As soon as the clutch is released, the shafts B and C go back to their normal positions, and the spring O operates to push the coned flange D back to its normal position, but as the back of it engages the tooth F it cannot pass, and the gear wheels are, therefore, held in their driving positions. The same operation brings the next speeds into operation in turn. To change up, it is necessary to go a step at a time, but in changing down it is possible to go right through from top to bottom gear or reverse if desired.








AUTOMATIC CHANGE SPEED GEAR

# Electrical Notes.

*By ANDREW STEWART, A.M.I.E.E.*

**Some Recent Developments in Electromobiles.**—Until the advent of the petrol omnibus, London stood fairly high in the list of health resorts, but the atmospheric conditions in and around Charing Cross lead one to conclude that the petrolification of the omnibus service is scarcely likely to prove an unmixed blessing, hence the news that a new electric accumulator is being tried, and has up till now given remarkably good results, will no doubt be welcomed as inspiring hope within the breast of those who are the victims of the latest phase of London's traffic problem.

Mr. Edison has so frequently "broken out," to use an American expression, in the accumulator line, and as frequently disappointed us, that it is quite encouraging to learn that he is wholly unconnected with the latest cell, and that it contains neither nickel nor iron. Moreover, it is a development of a type of cell which gave good results some twenty years ago, but was abandoned because of local action in the plates.

It appears that most of the infantile troubles of the new cell have been overcome, and the results achieved with an automobile that has been run over distances of 70 to 120 miles with one charge, seem to indicate that under certain circumstances the new cell should prove of value. Briefly, this new cell is a zinc and lead peroxide battery, *i.e.*, a plate of zinc is used for the negative, and a plate consisting of a lead grid filled with a paste composed of litharage and an undisclosed mixture, for the positive plate. This positive plate is therefore similar to the well-known Faure plate, so successfully used by the Electrical Power Storage Company in automobile work.

The special feature of the cell is that, when being charged, air is kept bubbling up between the plates by means of perforated pipes which are connected to an air receiver, this maintains a constant circulation of the acid, and ensures a smooth deposit of zinc.

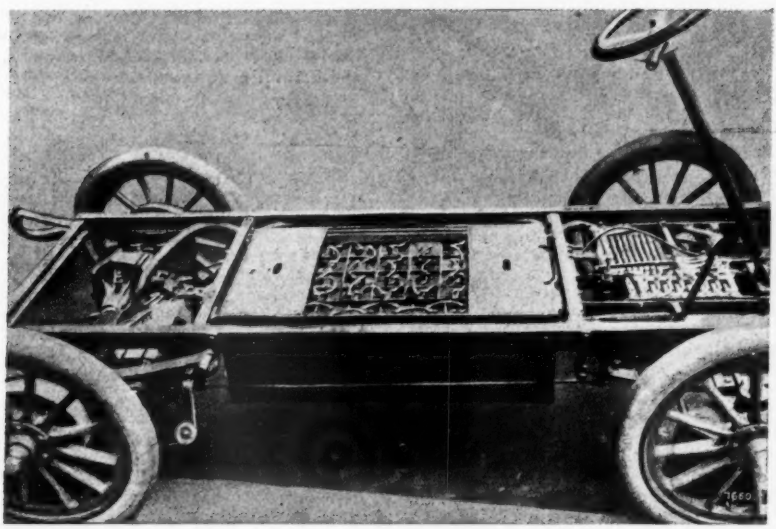
A test of a set of these cells gave 860 watt hours = 1·15 horse-power hours, from 42 lbs. of cell, and 20·5 watt hours per pound of cell. This, when compared with 8 watt hours per pound of cell for the well-known "Faure-King" traction cell, 11 for the "Fulmen," and 15 for the Rosenthall "National" cell is decidedly encouraging. The new cell, if the results achieved are maintained in practice, will mark a very distinct step in the construction of automobile cells, and one which will render practicable the development of electrically operated public service vehicles, free from the thraldom of the overhead trolly wire though not necessarily economically superior to the latter system, but in any case the electrically driven omnibus is more likely to prove a commercial possibility with the new cell.

*Apropos* the question of accumulator traction, we are able to illustrate the chassis of the ambulance electromobiles which are being put into service by the London County Council. The 45 E.P.S. cells are in the middle, they weigh about 10½ cwt., and have a capacity of 135 ampere hours. The ambulance can be run for 40 miles before recharging. The controller and resistances are in the forepart of the vehicle, while behind the battery box is an 8 h.-p. double commutator motor. This machine has two separate armature windings, so that series parallel control may be used; the motor drives through a double reduction gear to the differential on the rear shaft.

The controller gives forward speeds ranging from three to fifteen miles per hour, and one reverse speed. There are two electric brakes. The motor speed is 1,500 revolutions per minute, and though rated at 8 h.-p. will give 16 for short periods. Two ambulance stations are being arranged for, one at Bishopsgate Street and the other at St. Bartholomew's Hospital; these are connected to fifty-eight calling points all over the city, distinguished by a red cross on a white background.

**An Electrical Power Supply from Waste Steam.**—The Steel Company of Scotland, Ltd., are installing what is probably the first installation of any size of "Rateau" steam turbines driving electric generators, using the exhaust steam from the rolling mill engines, for this purpose. It is calculated that some 41,000 lbs. of steam per hour is wasted at the rolling mills, and by installing a "Rateau" steam accumulator

regenerator, a continuous supply of low pressure steam can be delivered at the turbines which run at 1,500 revolutions per minute, and give a maximum output of 1,350 kilowatts, depending, of course, upon the pressure, which will vary with the amount of steam available, though very ingenious arrangements have been introduced into the design of the regenerator to secure approximately constant pressure at the turbine with wide variations in the



CHASSIS OF A LONDON COUNTY COUNCIL AMBULANCE ELECTROMOBILE

supply of the exhaust steam. The output of electrical energy will be used to drive some auxiliary machinery and light the works.

**Cleaning Metal Surfaces by means of the Electric Current.**—A paper read to the Faraday Society a short time ago by Mr. H. S. Coleman, gave interesting particulars of a method of cleaning iron and brass articles, prior to the electro deposition of silver or nickel. The articles are wired up just as for plating, the articles being the anode, and the iron tank, containing a boiling solution of potassium hydrate, the cathode, i.e., the current flowed from the articles to the iron tank. With an E. M. F. of 1½ volts, and maintaining the current for five minutes, the grease appeared to be removed, but the surface of the work appeared to be coated with a brown stained deposit, which could not be removed by an acid or cyanide dip. The experiment was repeated with the current flowing in the opposite direction, with little better results, for while the grease and dirt were removed, the deposit remained, but it could be removed slowly with a cyanide dip. This experiment was again repeated, the current still flowing from the tank to the articles; as soon as the stain appeared, the direction of the current was reversed, and the stain disappeared, leaving the articles clean and bright. The results are undoubtedly due to electrolytic, and not to chemical action, as the same results were obtained with a cold bath, though the action was somewhat slower in a cold solution. A hot solution is preferable, as the grease is saponified, and remains in solution, while the lighter dirt floats on the surface, the grit falling to the bottom.

In order to determine the most suitable current for work of this kind, some experiments were made; these showed that about 8 amperes per square foot, and a potential difference of 2½ volts were satisfactory.

The advantages of this method of cleaning

are that the work is done in one-third of the time taken by the older method of scouring by hand, the work is chemically clean, as the electric current reaches parts which cannot be touched with a brush; the work is wired up just as for plating, so that the clean surface need not be touched until it is necessary to unwire it after plating.

## New Applications of Compressed Air.

Apart from its extensive employment in tunnelling and foundation work, compressed air is being applied in rapidly increasing measure to various branches of engineering work with much advantage. Pneumatic tools such as hammers, riveters, caulkers, drills and the like are fairly universal, but in addition to these, various new appliances of quite different character are now finding extensive use. The adaptation of compressed air for raising water is a natural and logical application. Various devices have been employed and are constantly being developed for this purpose. Some of these, such for instance as the air lift and forms of the direct displacement pump, fully hold their own by reason of convenience or compliance with conditions prohibiting other apparatus. But all appliances of the kind suffer from the drawback that they are not economical in operation. The chief objection to the direct displacement compressed air pump is that it does not utilise the potential energy of expansion and allows the air to escape at full pressure. This disadvantage is obviated by the return-air pumping system which embodies a most important invention. While the familiar direct displacement pump receives for each charge all the compressed air it will hold and rejects all of it, the return-air pump, working in a similar way, only uses the power actually necessary, and returns the balance to the intake side of the compressor. The return impulse of the air during expansion converts the displacement pump into an economical machine, and opens up great possibilities of additional uses for compressed air in permanent pumping plants in connection with water supply installations, and, in fact, for raising any liquids that can be dealt with by other pumps. Another new invention related to the return-air pump, although employed in quite a different direction, is the electro-pneumatic rock drill. This machine is of revolutionary character in design. The drill has no valve or valve motion. A small air compressor is fitted near the drill to be operated; two pieces of hose each connect one end of the compressor with one end of the drill cylinder, and there are no valves or obstructions to prevent the free flow of the air through the hose or into or out from either cylinder. The compressor is driven by a small electric motor mounted upon the same frame. As the compressor piston moves to and fro, the pressure rises in front of it and falls behind it, causing alternations of pressure at the two ends of the drill cylinder, and thereby operating the drill piston. After the first charge no additional air is taken in, except to compensate for leakage, and none is discharged. The drill piston is checked at each end by the elasticity of the air so that the force is not lost, but is transmitted to help the next stroke. Thus the important economy of the return-air pump is reproduced in another way. The new form of drill has been worked under exacting conditions for several years in the United States, and arrangements have been made for its manufacture upon an extensive scale.

# Engineering Progress.

**Ship Lifts.**—In a paper read before the Austrian Engineers and Architects' Society, and reported in the official organ, the *Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereines*, Dr. A. Riedler—speaking more particularly of the competition for designs for the projected ship lift at Preran—pointed out that the results of such competitions can never possess any widespread applicability, owing to the preponderance of local conditions influencing the design in every case. The two essential considerations, however, in the mechanical part are reliability in working and reasonable prime cost, and to these may be added as subordinate, though important, conditions, simplicity, ease of supervision, and accessibility and interchangeability of the parts. So far as the engineering part of these projects is concerned, it cannot be determined beforehand with the same degree of accuracy as is possible with the machinery, but is largely dependent on subordinate circumstances, all foundations and underground construction being influenced by the nature of the ground. Nevertheless, it is possible to fix as a standard for underground construction a limit that will be seldom reached in practice, and thereby ensure absolute reliability in working, by reducing the pressure, set up on the site by the structural work, to the natural pressure. This ideal cannot be realised in the case of lifts where concentric loads, deep foundations, high supporting walls, &c., are in question, at least not without great expense. On the other hand, in the case of inclined plane lifts, this broad condition can be easily fulfilled by adopting a suitable form of construction, the reliability of working being far greater than is attainable in engineering works as a rule.

The inclined plane system is also the only one that can be constructed at a low cost, but it is essential that only a single and sufficiently high speed should be used, and that the dry-haulage method should be adopted in order to save the weight of the water trough. All the plans hitherto proposed for affording an elastic support to ships when out of the water, are based on an erroneous idea, and calculated to defeat their own purpose, the only reliable way being to recognise the fact that all ships undergo deformation when loaded and afloat, and to adapt the supports to the actual form of the vessel and then fix them in a perfectly rigid manner. The hydraulic press forms the best method of carrying out this idea in practice, a number of such presses being so arranged on a truck that they can be applied to vessels of different build, and the press heads covered with a ring of hemp, which is forced against the hull by a pressure of 2½ atmospheres, the pressur at the contact surface being about $\frac{1}{10}$ atmosphere. Then, as the truck is drawn out of the water, the weight of the ship gradually acts on the rings, and the press valves must be closed. If the presses are mounted 6 ft. apart, the pressure in each cylinder will not exceed 40 atmospheres. Each press must be operated independently, so far as closing the valves is concerned, in order that the weight may be distributed uniformly; otherwise there is the danger of bending the hull plates where the internal pressure is low, and no guarantee that the more heavily loaded parts will not bulge to a dangerous extent. No difficulty will be encountered in packing the press plungers quite tightly, leather being a perfectly reliable material.

In distributing the pressure, the plan recommended is to mount every eight presses in two double rows on a separate truck, all the trucks being attached to a through girder. Wheels running in ball bearings are indispensable, the frictional resistance being only about one-third that of roller or plain bearings. The tractive force is preferably applied by rack and pinion, the strains being less than those in the ordinary mountain railway of this type and the movement freer from jolting. Low speed electro-motors would furnish the motive power, two pairs of cogwheels being sufficient for the reducing gear. Springs on the truck wheels are not essential, the hull and track being sufficiently elastic to take up the slight irregularities in the rails, joints, &c.; and in this system no duplication of the lifting plant is necessary, since the rate of haulage can be increased to 10 ft. per second, owing to the low dead weight and absence of water.

The plant for discharging the ship into the high level water may be greatly simplified by providing a turntable (turning through an angle of 16 deg.) of the same gradient as the rest of the track, so that the train of trucks and their load can be run down into the water without change of gradient, only the direction of movement being reversed. The turntable can be operated by a couple of electro-motors at opposite sides. This arrangement dispenses with the necessity for any protecting wall at the high level, and no extensive masonry is required anywhere, the pressure on the site being no greater than the natural pressure.

**Cantilever and Tower Cranes at the Vulcan Shipyards, Bremen.*** — The cantilever cranes (Fig. 1) in use at the Vulcan shipyards, Bremen, are mounted on scaffoldings long enough to enable them to serve vessels

* *Le Génie Civil.*

600 ft. in length. As originally constructed, this arrangement proved less satisfactory than was anticipated, owing to the fact that the stocks were laid at an angle of about 45 degs. to the river, so that some inconvenience was experienced in transporting materials to the stern of the vessel. To obviate this difficulty, a track was laid inside the base of the platform, and the materials were unloaded from the trucks by a small crane (shown at the bottom of Fig. 1), which laid them down at a spot whence they could be lifted by the cantilever crane. Even this modification did not give the desired facilities, and it has now been replaced by the provision of two travelling wall cranes, running the whole length of the scaffolding, underneath the cantilever crane and capable of discharging beyond the centre line of the vessel on the stocks.

A more advantageous type of crane, inasmuch as it is quicker to operate, is the tower crane (Fig. 2), three of which are in use at the same yard. The largest is 110 ft. high, the hook being 93 ft. above the rails, and the working radius is 52½ ft. for a load of three tons, or 29½ ft. for six tons. Crane tracks, 19½ ft. gauge, are laid on each side of the stocks, and ordinary gauge tracks for wagons and small portable cranes, are arranged inside. For loads over six tons, the hooks of the two opposite tower cranes are attached to a traverse carrying the load. The cranes can be run at a speed of nearly 200 ft. per minute, and will lift a full load at the rate of 50 ft. per minute, or a half load at twice that speed. The peripheral velocity of the swing motion is 245 ft. and the velocity of the crab 50 ft. per minute. The various movements are operated by independent electromotors, fed with continuous current from a conduit near one of the rails.

**Improved Apparatus for the Analysis of Flue Gases.***—The "Ados" recording apparatus for the periodical analysis of flue gases has been improved by the addition of an aspirator pump for drawing in the gas, the *modus operandi* being as follows:—The gas to be tested is drawn by the aspirator, *Q*, through the pipe, *D*, over the metallic vessel, *C*, and through the pipe, *E*. At the same time, water

* *Elektrische Bahnen und Betriebe.*

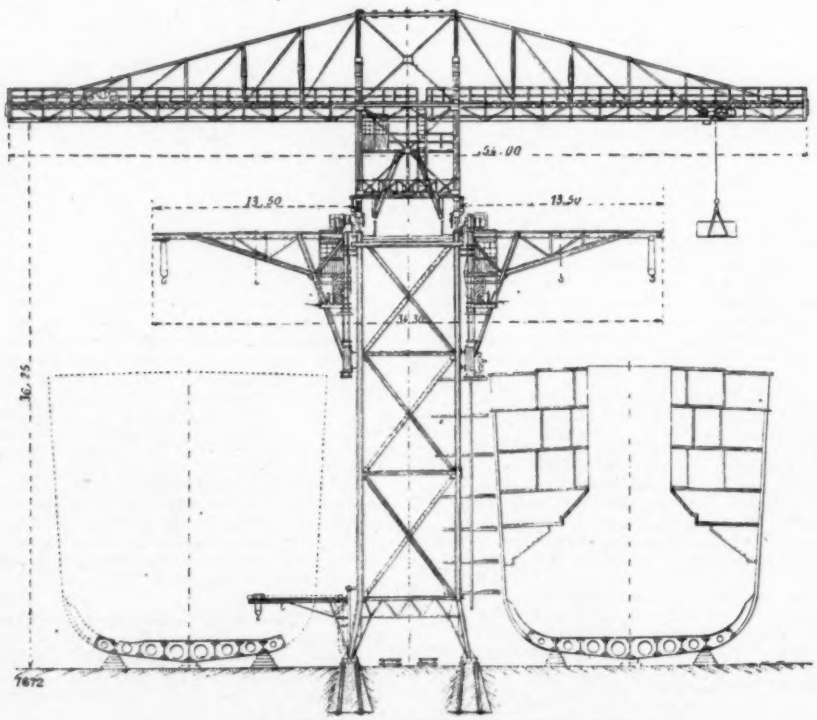



FIG. 1.—CANTILEVER CRANE AT THE VULCAN SHIPYARDS, BREMEN.

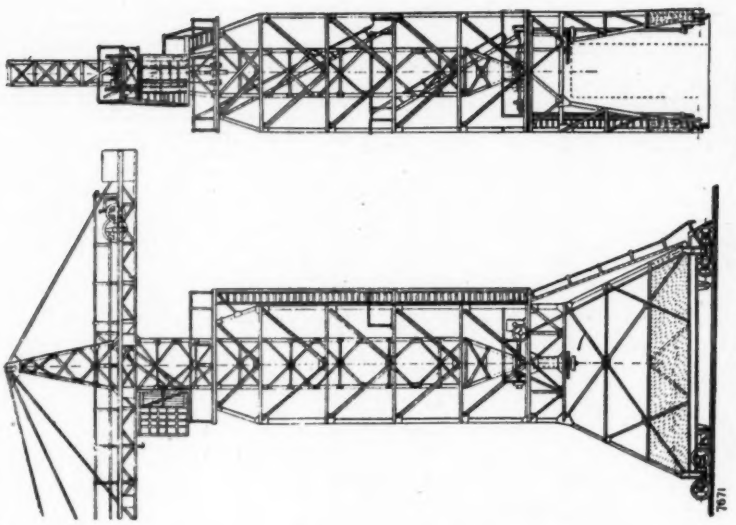


FIG. 2.—TOWER CRANE AT THE VULCAN SHIPYARD BREMEN.

flows *viâ* *L* into the box, *K*, which is in two divisions, the upper one becoming filled with water, the pressure of which forces a portion of the liquid in the lower division into *C*, thus sealing the tubes *D* and *E*, and imprisoning a sample of the gas in *C*. As soon as the sealing liquid reaches the pipe leading to the rubber bulb, *P*, the pressure in *C* is equal to that of the external air. The further ascent of the sealing liquid forces the gas sample into the potash vessel, *A*, and thence after absorption of carbon dioxide, into *B*, where it raises the bell, *N*, and actuates the recording pencil, *M*, which marks on the drum, *O*, a line corresponding to the volume of gas remaining unabsorbed. By the time sufficient gas for a test has been displaced by the liquid rising in *C*, the water in *K* will have reached the syphon, *H*, whereupon *K* is emptied automatically, and the apparatus is in position for performing a fresh analysis.

**Hydraulic Compressor Plant at a German Colliery.***—The water supply for

* *Gluckauf.*

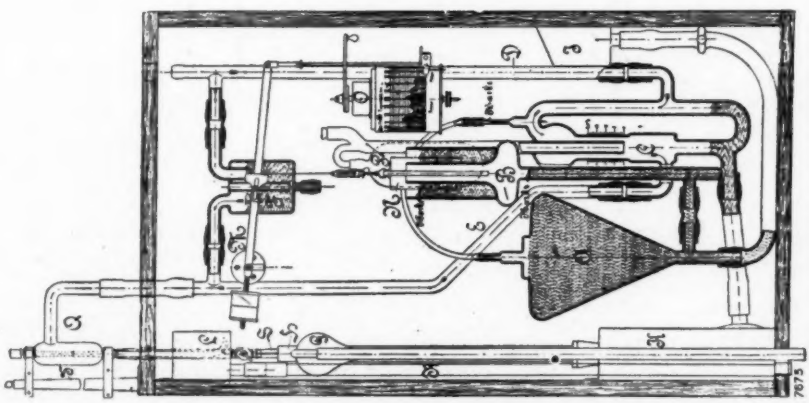


FIG. 3.—APPARATUS FOR THE ANALYSIS OF FLUE GASES.

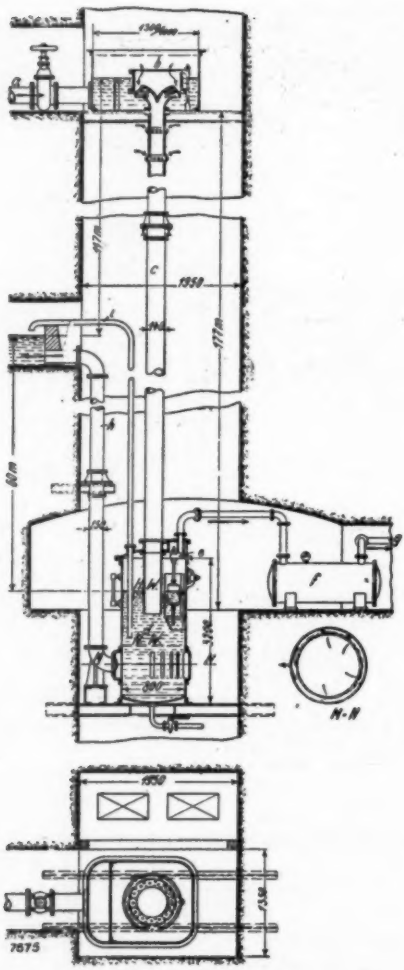



FIG. 4.—COMPRESSOR PLANT AT A GERMAN COLLIERY.

the hydraulic compressor plant recently erected at the Holzappel pit, Laurenburg, is derived from five artificial lakes, and is conveyed through 600 yards of 12-in. main, to the central shaft at the colliery, which it enters at a depth of about 165 ft. below bank, with an effective head of 387 ft. to the tail race (a gallery discharging into the Lahn valley). This, with a flow of 260—480 gallons per minute, gives an available water-power of 32—58 h.-p. The compressor is built in the shaft, and the water is supplied through the 7-in. pipe, *a* (connected with the 12-in. main) into a tank fitted with the suction head, *b*, whence it descends the 5½-ft. pipe, *c*, air being drawn in and compressed during the fall. The air separator, *d*, which is 35 in. wide, and 10½ ft. high, receives the mixed water and air, and discharges the former through the upcast delivery pipe, *h*, into the tail race gallery. The compressed air, under a pressure of 2½ atmospheres, leaves the separator through a 2½-in. pipe, traversing the cylinder, *f*, and entering the pipe, *g*, which is connected with the compressed air main from another shaft at the same colliery.

The construction of the suction head is shown in Fig. 5. The air enters through the perforated cover, and is drawn into the down pipe through four concentric rows of ⅝-in. brass tubes The head itself is supported on three adjustable standards, enabling it to be set in the proper relative position to the water level.

To facilitate the separation of air and water in the separator, the issuing water is caused to flow through a number of slits into an annular chamber (section *M—N*, Fig. 4) before reaching the upcast pipe, the slits being situated on the

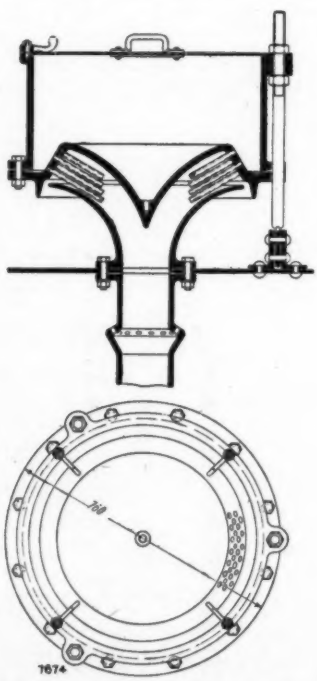



FIG. 5.—COMPRESSOR PLANT AT A GERMAN COLLIERY.

side opposite the latter, and of such dimensions that the effluent velocity of the water is less than the ascending velocity of the imprisoned air bubbles. A float valve, *e*, prevents any escape of water into the air main when more air is drawn from the main than the compressor can supply; and an escape pipe, *i*, is provided for the converse contingency. The average efficiency of the plant is 81 per cent.; no supervision is required, the prime cost and working expenses are low, and the plant is long lived, owing to the small wear and tear.

# The "McKenna" Process of Renewing Steel Rails.

By far the greater number of the many thousands of tons of rails that are annually thrown out of service by our railway companies owing to slight wear having rendered them unfit for the requirements of a first-class road, have to be sold as scrap. Only a proportion of them are relaid on branch lines, sidings, or in contractors' yards, and a certain number made use of for structural purposes. In recognition of the fact that there was a large demand for rails of a section slightly smaller than that of the standard, the "McKenna" process was established on a commercial scale eight or nine years ago in the United States, and the success there met with induced those interested to establish the system in this country.

To that end the English McKenna Process Co., Ltd., was formed, and works laid down on a convenient site at Seacombe, Birkenhead. The "McKenna" process, it may be explained, has for its object the restoration of worn or defective rails, without the necessity of remelting, to a true section slightly smaller than that of the original rail, and the plant wherewith this operation is effected has features of such interest as to merit general attention.

The works themselves have been laid down on a site occupying twenty-seven acres, and convenient access for raw material and an outlet for the finished product is furnished by sidings connected with the Wirral Railway and the Mersey Docks and Harbour Board, and by docks on the River Mersey, situated within 300 yards of the works.

The erection and equipment of the works occupied the remarkably short space of time of twelve months, and was carried out under the supervision of Mr. S. Thornely Mott, chairman; Mr. Wm. Tozer, managing director; Mr. George F. West, director

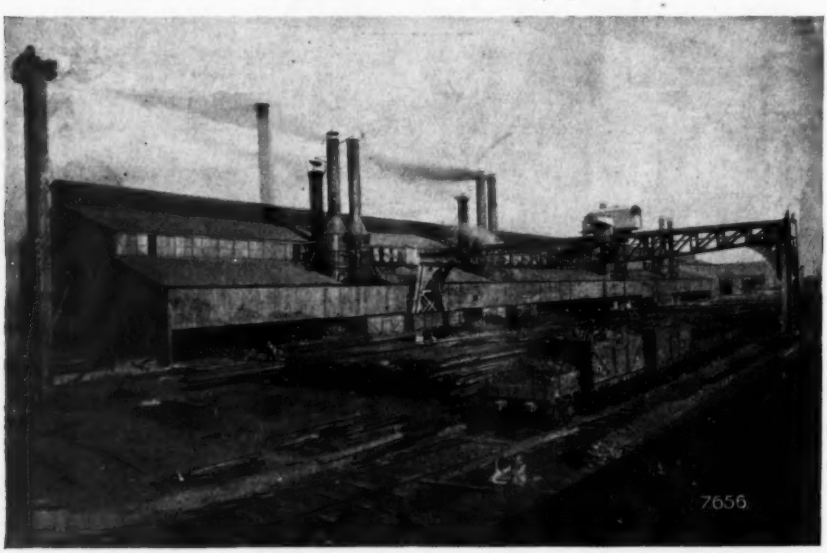



FIG. 1.—VIEW OF THE "MCKENNA" CO.'S WORKS.

and secretary; and Mr. F. A. Knight, the company's engineer, who acted as resident. The buildings are of galvanised iron with steel frames, and the whole of the plant, with the exception of some Buffalo Co.'s fans for supplying air to the furnaces, is of British manufacture. The siding in which the raw material is brought in adjoins the buildings, and is spanned by an electric travelling crane by Messrs. J. H. Wilson & Co., Seacombe, by which the rails are lifted and stacked or delivered on to skids for delivering them to the furnaces. A view of this side of the works, in which is shown the sidings and crane, is given in Fig. 1.

FIG. 2.—INTERIOR OF HOT MILL.

Following the course of a rail to be treated, through the various operations, it is first deposited by the yard crane on to skids, across which it is pulled by hand, and if badly worn and finned is passed on to one of two grinding machines in which the fins are removed by face grinding corundum wheels of 18 in. diameter, the rails being fed through the machine and steadied by means of suitable rolls. Power is supplied to the machine by an independent motor, the feed rolls deriving motion through a variable speed gear and bevel and worm gearing, the grinders being driven by pulleys belted to the motor shaft. Having been ground, the rail is passed to another set of skids from which it is removed by the yard crane and conveyed to another set of skids facing one of the charging machines, of which there are four, one serving each furnace. These machines, which are 40 ft. in length and 18 ft. wide, are framed structures which travel sideways on five rails laid in front of the furnaces, and their function is to lift the rails from the skids, place them in required position in front of the furnace and push them in. The first operation is effected by a toggle mechanism, the second by a rack and pinion gear, and

the third by chain-driven bogie, all of which motions, including that of the machine itself, are derived from a 25 b.h.-p. three-phase induction motor.

The furnaces, of which there are four, are of the reverberatory type, two having a floor area of 35 ft. by 10 ft. and two 48 ft. by 10 ft. The smaller pair heat the rails delivered at the end of the roll train, and the larger pair those about two thirds of the way down, the latter being utilised for rails that require very little rolling.

The products of combustion from the furnaces are utilised for heating eight "Hyde" waste heat boilers, which assist the Babcock and Wilcox boilers in supplying steam for the power house. They are 250 h.-p. each and work at 165 lbs. pressure.

The boilers, of which there are two to each furnace, are of the vertical water-tube type, and consist of a central vertical water-leg of 28 in. inside diameter and 24 ft. 6 in. long, closed by a door at the lower end, and terminating at the upper end in a vertical drum 8 ft. high and 6 ft. 6 in. in diameter. The upper end of the drum is dished and stayed from the top of the water-leg (which enters the drum by 6 in. for that purpose) by eight 2-in. tie-bars with box-nut adjustment. The lower end of each brace is flanged out and riveted to the top of the water-leg, while the upper end is jointed between angle plates inside the crown.

The lower end of the steam drum is flat, and stayed to the top by eight 2½-in. stray-bolts. It is pierced for 128 water-tubes of solid-drawn Siemens steel, which descend from it vertically, and are bent round at their lower ends, and communicate with the water-leg. These tubes are arranged in five circles, the three inner circles comprising 77 tubes of 3 in. diameter and the two outer circles 51 tubes of 4 in. diameter. The waste gases pass round the water-leg below the tubes, then up between the tubes, round the steam-drum, and away at the top. The outer casing of the boiler consists of a cylinder built up of cast iron flanged plates, lined with firebrick nearly up to the steam-drum, and provided with numerous inspection-doors. Five rings, each of six plates, go to make the cylinder, which is about 8 ft. in diameter by 25 ft. long. It is surmounted by a sheet-steel

FIG. 3.—VIEW SHOWING MOTOR, MAIN SPUR WHEEL, AND PINION.

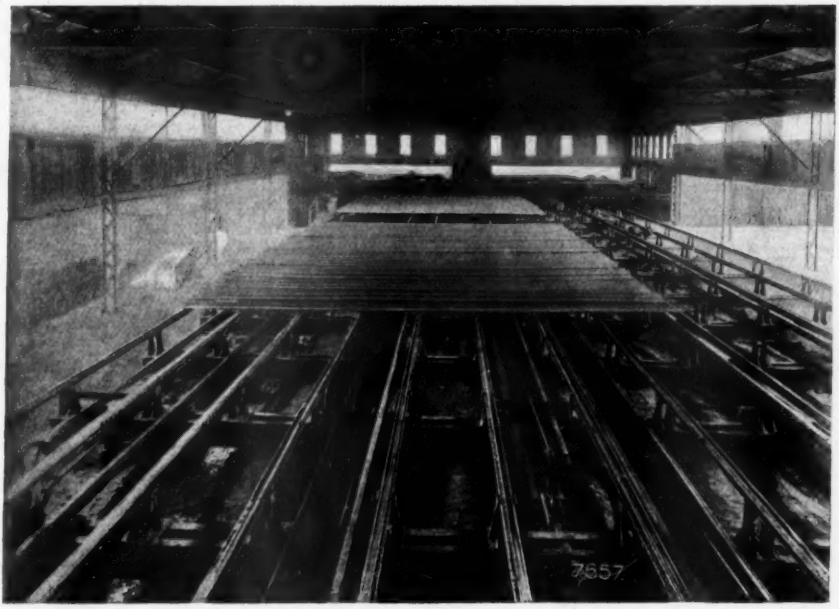



FIG. 4.—THE HOT BED.

conical uptake, forming the base of a steel chimney, 3 ft. 8 in. in diameter, the upper end of which is closed by a damper. These boilers were made in England from designs furnished by the patentees, Messrs. Hyde Brothers & Co., of Pittsburg, and they are now being introduced into this country by Messrs. James H. Tozer & Son, Ltd., of Westminster, who have acquired the sole rights of manufacture.

After the rail has been sufficiently heated, it is withdrawn from the furnace on the discharging side by a set of drawing-out rolls on to a transfer table, the function of which is to deliver the rails to the roll train. There are two of these machines, each serving two furnaces, one being operated by a 50 h.-p. motor and the larger by one of 75 h.-p.

The drawing out rolls are assisted in their operation by the live rolls of the table, of which there are eight, each driven independently from a side shaft.

When the whole of the rail is on the table these rolls, which are actuated by the large motor, are stopped and a set of traversing dogs, driven by a 7½ h.-p. motor through pulleys and wire ropes, started, which push the rail across the table on the skids, from which they are passed to the roll train. The dogs, in making their return across the table, pass underneath the rails just delivered from the furnace.

The rolling mill, shown in Fig. 2 (in which may also be observed the furnaces and the "Hyde" boilers on the outside of the building) is 422 ft. in length, and contains six pairs of rolls and seven tables. The rolls are spaced out at intervals of increasing length, corresponding roughly to that of the rail as it passes down the tables.

The beds are 4 ft. 7 in. wide, and are composed of a pair of 10-in. channels, which form the sides, and carry cast-iron plates and side angles at the top. The channels are supported on concrete piers every 12 ft., so that the top of the bed is about 2 ft. 8 in. above the floor-level. Every 6 ft. along the bed is a live roller, 9 in. in diameter, running in eye-brackets bolted to the channels. The live rollers of every bed are all driven by bevel gear from a shaft running along the side of the bed, which is in turn driven by gearing from a 7½ h.-p. motor. Each bed is quite independent of the others, and its live rollers, the function of which is to

convey the rail from one roll stand to the next, can be started or stopped quite independently of them. The rolls themselves are 2 ft. 4 in. in diameter and 3 ft. 6 in. long between the housings. They are geared together by steel helical wheels of 5 in. pitch, situated in a separate pair of housings. Between each gear-wheel and its roll is a massive wobbler-shaft supported in a spring-borne swinging cradle, to allow for differences in height or alignment of the parts connected. All the housings of each mill are bolted down to heavy slot-rails, making adjustments easy and keeping the whole arrangement rigid.

Each set of rolls is driven by its own three-phase induction motor (Fig. 3), the six motors being situated in a long alley screened off from the rolling-mill by a partition of galvanized iron, through which the second-motion shafts pass. The motors were built by Messrs. Siemens Brothers & Co., Ltd., and work direct off the 440-volt 25-cycle supply from the power-house. They are of 500 h-p., and run normally at 300 revolutions per minute, this speed being reduced in the ratio of about four to one for the rolls by the large helical gear. The gearing is of 5 in. pitch and 18½ in. wide on the face. The pinion is of 38·2 in. pitch diameter, with twenty-four teeth, and the wheel of 12 ft. 5·6 in. diameter, with ninety-four teeth, both wheel and pinion being shrouded to the pitch-line. The maximum torque of the motor is specified as not less than 2·75 times the full load torque, at a constant voltage. The rotor winding is symmetrically disposed in half-closed slots. One end of each of the three sections is joined up to a neutral point, the other three ends being carried through the centre of the shaft to three copper-slip rings, from which the current is collected by carbon brushes. The motors are built to stand the violent and sudden overloads due to the nature of their work, and will carry their full load continuously for six hours without a greater temperature rise of any part than 72° F. above the atmosphere.

The rolls may be set in motion either by the rolls-attendant or by the engineer at the switch-board in the power-house, in the latter case, the starting being effected by the switching on of an automatic starter. This is a special piece of apparatus, the action of which is fully described and

FIG. 5.—RAIL-ENDING MACHINE.

illustrated in a booklet issued by the company, and from which much of the information given here has been extracted.

The passage of the rail through the six rolls to the final table occupies about forty-five seconds, and on leaving the rolls passes to the hot saws to be cut to the required length. There are three saws, each 3 ft. 6 in. in diameter, and belt-driven from an overhead motor, the distance separating the first two being 14 ft., that between the second and third being adjustable up to a maximum of 33 ft. Live rollers, driven by a 10 h.-p. motor, bring the rail from the roll train into position for cutting, where it is cramped by a lever and toggle arrangement, and the saws advanced by means of hydraulic cylinders, and the ends cut off.

Owing to the difference in the rate of cooling between the head and foot of the rail, consequent upon the difference in their weight and shape, it is necessary to give a considerable camber to the hot rail, to ensure its being straight after cooling.

This operation is effected by a cambering machine, in which the rail is made to pass between three staggered rolls revolving together with their axes vertical. The front roller is fixed, but those behind are capable of being swung, to give a greater or less curvature to the rail as required. From this machine the rail is passed on to the hot bed, illustrated in Fig. 4. It is a grid-like structure, 140 ft. long and 40 ft. 6 in. wide, and upon it the rails are placed to become cool.

Every 10 ft. down its length double joists run across it, carried on piers, and these joists support longitudinal rails spaced about 3 ft. 6 in. apart. The rails form the top of the hot-bed, which is 2 ft. 5 in. above the floor level. From the rear, or incoming end of the bed, three bogies run down nearly to the other end, one in the centre of the bed and one close to each side. They run on rails a foot below the top of the bed, and are pulled to and fro by endless wire ropes, returning under the bed and passing round drums at the back. The bogies are driven by a 25-horse-power motor and move simultaneously, as the three driving drums are all geared to the same shaft. Each bogie has a hinged finger projecting above the level of the hot-bed, which can be depressed against the action of a weight in the forward direction, but is rigid against pressure, tending to force it backwards. As the bogies come

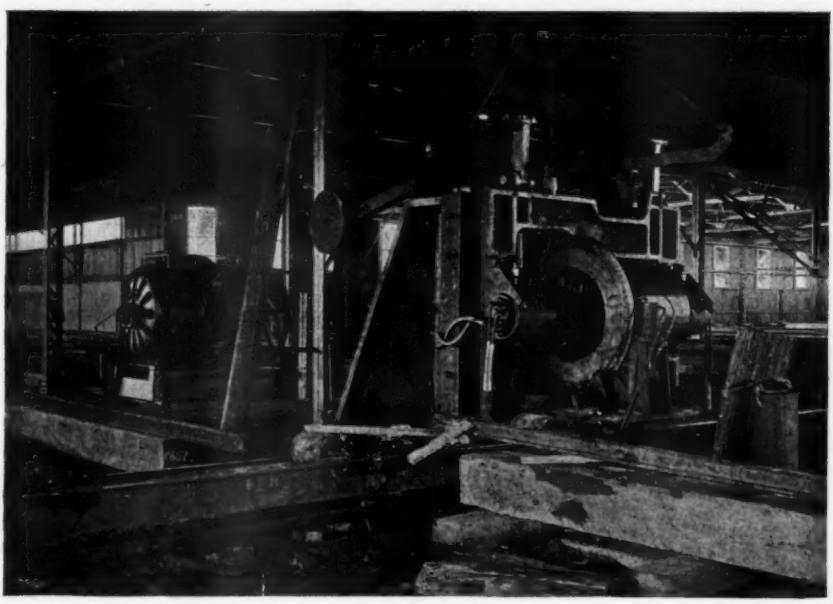


FIG. 6.—COLD SAW

FIG. 7.—VIEW OF POWER HOUSE.

backwards, the fingers will pass under a rail lying on the hot-bed, but on their return journey the fingers push the rail down towards the other end of the bed.

At the delivery end of the hot-bed are other motors, which drive another set of bogies similar to those thus described. These bogies run under the cooled rails, and on returning pull them along to the end of the bed. The motors working both the pushing and pulling bogies are controlled by men on raised platforms at either end of the bed, who have a clear view of the complete bed.

To accurately straighten the cold rail it is conveyed from the hot-bed to one of the four straightening presses by means of live rollers. These presses, which resemble in construction ordinary punching machines, are actuated by a motor mounted at the top of the frame, and which drives a rising and falling ram by means of suitable reduction gear and a crank.

The rail lies along the table of the machine under the ram, resting on two rollers 5 ft. 6 in. apart, and guided sideways between vertical rollers adjustable in the bed. The ram descends midway between the supporting rollers on any point of the rail determined by the attendant, who bends the rail when and where he thinks fit, judging almost entirely by his eye.

The rail, when straightened, has its ends trimmed up, and its length accurately planed by one of the two rail-ending machines (Fig. 5). The rail is measured with a gauge or tape measure, and marked to length. The end is then cramped in the box of the machine, and a revolving cutter shaves off the face of the section, the box being automatically fed forward until the cut has reached the mark. The other end of the rail is then treated in a similar manner.

Where a greater length has to be taken off at the ends, an unusual type of machine is employed, and which is shown in Fig. 6. It is a cold saw, the cutting element of which consists of a disc of steel plate, rotated at an enormous speed, and forced through the rail to be cut. The disc is 50 in. in diameter and $\frac{5}{16}$ in. thick, and is

driven at a surface speed of 27,500 ft. per minute from a 125 h.-p. induction motor, and will go through a 50-lb. or 60-lb. rail in about five seconds. The saw spindle is carried in bearings in a saddle sliding vertically on the framing of the machine, and counterbalanced by weighted levers. An hydraulic cylinder, connected by a lever to the rocking-shaft, feeds the saw downwards.

The concluding operation is that of drilling the rail ends for the fish-bolts. Special machines, constructed by Tangyes of Birmingham, perform the operation of drilling the two holes through the web at each end, the holes being oval in shape to allow for expansion and contraction. The finished rail has now passed right through the works, and is ready for being loaded into trucks. This is accomplished in a simple manner, as, owing to the rail level being several feet lower than that of the yard, the rails can be simply slid off the skids into the trucks without handling in a crane. It will be gathered from the foregoing description that the whole of the plant is electrically driven, and it only remains now to describe the leading features of the power-house, which are not without interest. This was designed and laid out by the engineer to the company, Mr. F. A. Knight, and consists of a boiler room and an engine room, both steel frame structures, the former with a galvanized iron covering, the latter having brick walls. The boiler equipment consists of two pairs of "Babcock" boilers working at 165 lb. pressure and supplying steam superheated to 500° F.

They form, strictly speaking, a reserve steam supply, as the "Hyde" waste heat boilers suffice for all circumstances except the sudden heavy demands for steam, which are incident to the working of the rolls.

The water supply is from a well, being raised therefrom by an "Alley and McLellan" air compresser to a storage tank 60 ft. high. A cooling tower of the "Donat" type, capable of dealing with 180,000 gallons of water per hour, has been installed. The engine room equipment consists of three "Willans-Parsons" turbines, direct-coupled to "Siemens" three-phase alternators of 750 kilowatts generating current at 440 volts, with a periodicity of 25 at a speed of 1,500 revolutions per minute. They are capable of giving an overload output of 950 kilowatts for one hour. One feature may be noticed in connection with the condensing plant, namely, that it is driven by continuous current motors in contradistinction to the remainder of the machinery. Current is supplied to these by two "Bellis-Siemens" 50 kilowatt sets generating at 250 volts, or from two "Siemens" rotary converters with transformers, one having an output of 150 kilowatts and the other of 50 kilowatts. Also in the engine room is the steam-driven air compressor for the air lift, and a 50-ton "Buckton" testing machine.

The switch board for the control of the plant is 29 ft. long and 6 ft. 9 in. high, and is made up of 15 white marble panels. The first six are feeder panels and control, amongst other feeder circuits, those of the 500 h.-p. motors driving the rolls, the ammeters for these circuits readily affording a means of tracing the progress of a rail through the rolls. The seventh panel controls the alternating side of the rotary converters; the eight is the station-panel, and is followed by three generator panels; the next two control the direct-current sets, the fourteenth the direct current side of the rotaries, and the last the arc lighting circuits.

Next the engine room is a light repair machine shop which adjoins a shop used for roll-turning, containing two roll-turning lathes by Messrs. London Bros., Glasgow.

We understand that the works are capable of turning out about 200 tons of rails per day, and that, since they were started in the early months of last year, as much work has been offered as they have been able to deal with.

It should be mentioned that the rails treated usually show an ultimate tensile stress of from 40 to 45 tons per sq. in., and an elongation of from 20 to 25 per cent. on 3 in.

In conclusion, we have to thank the directors for their kindness in enabling us to visit the works, and Mr. F. A. Knight, the resident engineer, for explanations of the various processes.

# Metallurgical Progress.

*By PERCY LONGMUIR.*

## The Iron and Steel Institute and the American Institute of Mining Engineers.

**The Crystallography of Iron.**—Messrs. Osmond and Cartaud have on other occasions dealt with this subject, and the conclusion then drawn was that the three allotropic states of iron—α, stable below $A_2$; β, stable between $A_2$ and $A_3$; and γ, stable about $A_3$—all crystallise in the cubic system. By means of a most exhaustive crystallographic examination the authors confirm this earlier conclusion. Details of the methods followed hardly possess a general interest, still the following tabulated results are worth noting.

| | α. | β. | γ. |
|---|---|---|---|
| Planes of translation ... | $a^1$ (111) difficult | None known | $a^1$ (111) easy |
| Folds ... ... ... | Dominant | Exclusive | Absent |
| Mechanical twinning: Planes of twinning | $a^1$ (111) | None known | $a^1$ (111) |
| Mechanical twinning: Planes of junction | $a^2$ (112) | None known | $a^1$ (111) |
| Twinning by annealing: Planes of twinning | None known | None known | $a^1$ (111) |
| Twinning by annealing: Planes of junction | None known | None known | $a^1$ (111) |
| Face of maximum hardness ... ... | $a^1$ (111) | ? | $b^1$ (011)? |
| Planes of easiest etching | $p$ (001) | $p$ (001) | $p$ (001) |

Admittedly these results offer difficulties in the way of interpretation, and the authors candidly confess that the only positive conclusion to be drawn is that the three allotropic varieties of iron, although they all crystallise in the cubic system, present well marked specific characters, and cannot have the same internal structure.

**The Constitution of Iron Carbon Alloys.**—At the outset Professor Sauveur discusses the Roberts-Austen Roozeboom diagram, and shows that the transformation of graphite into cementite, as indicated by the diagram, cannot logically occur. The view advanced is that graphite does not intervene in any change occurring below the solidification range. However, to test the matter some pure electrolytic iron was melted with an excess of sugar charcoal, and after melting the crucible and its contents were allowed to cool very slowly in the furnace. These conditions were favourable to the production of a pure iron carbon alloy in a state of stable equilibrium. Absence of impurities and extremely slow cooling should promote stable equilibrium, that is, these conditions should promote the transformations which theoretically are assumed to take place at the various thermal critical points. The resulting alloy contained 4·354 per cent. total carbon, and this amount should yield during solidification 2·40 per cent. graphite; whilst actually the alloy contained 3·066 per cent. graphite. Not only did any graphite fail to combine with iron at the critical temperature of 1,000°C., but some of the cementite actually broke up into temper carbon and iron during the very slow cooling from this temperature. Other experiments are quoted in which the graphite could not be made to combine with iron. Repeated failures to induce this combination, even under the most favourable conditions, appear to be conclusive evidences that the graphite which forms during the slow solidification of highly carbonised iron takes no part in any further transformation and is to be found in the cooled alloy, not by "lag" but by right. Applying the foregoing to malleable castings, it is shown that if the author's view of the formation of graphite be accepted, then white cast iron must be regarded as being in a state of unstable equilibrium. Reheating such an iron will result in a certain return to the stable state, which means the formation of a certain amount of temper carbon. This behaviour of white cast iron is very similar to that of hardened steel subject to tempering. But white cast iron and hardened steel are in an unstable condition, the former because of too rapid cooling through the solidification period, the latter because of too rapid cooling through the critical range 700°C. or thereabouts. Both metals have a latent tendency to assume a more stable condition, which means the formation of graphitic carbon in white cast iron. Both metals will show a partial return to a more stable condition if they are heated to a temperature which

may be considerably below the critical point through which the metal was cooled too quickly.

**The Influence of Silicon and Graphite on the Open Hearth Process.**—Mr. A. S. Thomas lays stress on the importance of a suitable covering slag in the open hearth process. This slag is naturally derived from the silicon of the pig metal charged, and provided the initial iron contains the right silicon good results follow. Where a low silicon pig iron is used, that is below 1·25 per cent., free silica or slag may be added with the charge to form a covering slag. This practice is not altogether good, and the low silicon in the charge results in a greater oxidation of iron. The author finds that the use of low silicon pig results in a loss of iron, not only by oxidation through exposure to the flame of the furnace but also by the loss of iron in the oxides, owing to the smaller quantity of oxides which are used. Further, there is never the same vigorous action in the furnance when low silicon pig is used, owing to the lower inital heat in the charge when molten. The author's experience of high silicon pig is that with a silicon content of 2 per cent, and over the banks are seldom, if ever, fluxed; but that bad bottoms very often occur if the furnaceman lags behind, and does not add his oxides quickly enough to keep his slag from becoming viscous. Therefore in the acid open hearth process an iron neither too high nor too low in silicon must be used, and the author's experience is that a silicon of from 1·25 to 2·0 per cent. is ideal for the acid open hearth melter. A suggestion is made that low silicon hematite irons might be worked on a basic bottom.

Such a method would not be a basic process, and only enough lime, 3 to 5 per cent., need be added to render the slag just sufficiently basic to prevent the banks and bottom being fluxed. It would be an acid process on a basic bottom and the quality of the resulting steel would be superior to the average quality made on acid bottoms. Turning to graphite, the author is of the opinion that this form of carbon has received too little attention. Founding his remarks on observations of a 160-ton "Talbot" furnace working on hematite iron, the author notes that silicon is not a trouble to the same extent as graphite. The fluxing effect of silicon is easily neutralised by the addition of lime, but when a charge high in graphite is worked the surface of the bath is covered with a layer of kish. Under these conditions the bath lies dormant until the carbon is partly burnt off and partly converted into the combined state. As soon as this takes place the bath becomes active again. Addition of oxides or mechanical agitation of the bath does not affect matters, and the bath must lie until the graphite is partly burned off and partly converted into the combined form. The average time in pouring a ladle of low graphite iron into the furnace is only about thirty minutes, whilst it takes from one-and-half to two hours to pour in an equal quantity of high graphitic iron. This is due to the fact that when the carbon is in the combined form a steady reaction takes place throughout the whole operation. When the carbon is in the form of graphite the reaction is delayed for some time, therefore from three to five tons only may be poured in at one time, in that when the reaction does occur it is so violent that slag and often metal are thrown out of the doors. These delays considerably retard the process, and the author finds that when the graphite is low an increased output and a decrease in wear and tear of furnace result.

**The Kjellin Electric Steel Furnace.**—Mr. E. C. Ibbotson records results obtained with this furnace. Thus, at Gysinge, during the year ending May 31st, 1906, a fixed furnace giving 1 ton of steel per tap produced 950 tons of tool steel and special steel ingots. The bulk of this steel was made from charges composed of about 80 per cent. Swedish white iron and 20 per cent. of steel scrap, the percentage of carbon being regulated by the addition of briquettes. In ordinary practice, charges with briquettes are completed in 6½ hours, and without briquettes in 5 hours. This is illustrated by the following typical charges: White pig-iron, 1457 lbs.; steel scrap, 439 lbs.; briquettes, 220 lbs.; 50 per cent. ferro silicon, 17 lbs.; 80 per cent. ferro manganese, 15 lbs.; aluminium, 1 oz. The times, strength of current, and units consumed for the charge, were as follows:—

| Time. | Current. | | —— |
|---|---|---|---|
| | Kilowatts. | Units. | |
| 5.30 | 125 | — | Charging two-thirds of the pig-iron |
| 6.00 | 145 | 67·50 | — |
| 6.30 | 160 | 76·25 | — |
| 7.00 | 170 | 82·50 | Charging of the remaining one-third of the pig and the scrap |
| 7.30 | 170 | 85·00 | — |
| .00 | 165 | 83·75 | Clear melted |
| 8.30 | 165 | 82·50 | Briquettes added |
| 9.00 | 165 | 82·50 | — |
| 9.30 | 165 | 82·50 | Briquettes added |
| 10.00 | 165 | 82·50 | — |
| 10.30 | 165 | 82·50 | Briquettes added |
| 11.00 | 165 | 82·50 | — |
| 11.30 | 165 | 82·50 | — |
| 12·00 | 130 | 73·75 | Ferro-silicon and ferro-manganese added. Tapped. |
| 6½ hours | — | 1046·25 | |

A second charge, consisting of steel scrap, 1372 lbs.; white iron, 914 lbs.; ferro silicon

4·5 lbs.; ferro manganese, 6·5 lbs.; and aluminium, 1 oz., was as follows:—

| Time. | Current. | | —— |
|---|---|---|---|
| | Kilowatts. | Units. | |
| 7.00 | 125 | — | Charging all pig and one-half scrap |
| 7.30 | 145 | 67·50 | — |
| 8.00 | 135 | 75·00 | — |
| 8.30 | 160 | 78·75 | Charging scrap |
| 9.00 | 165 | 81·25 | — |
| 9.30 | 170 | 83·75 | — |
| 10.00 | 165 | 83·75 | Clear melted |
| 10.30 | 165 | 82·50 | — |
| 11.00 | 165 | 82·50 | — |
| 11.30 | 165 | 82·50 | — |
| 12·00 | 135 | 75·50 | Ferro-silicon and ferro-manganese added. Tapped |
| hours | — | 793·00 | |

Analyses of the materials charged, and of the resulting steel, were as follows:—

White Iron (Herrang).

| | Per cent. |
|---|---|
| Total carbon ... ... ... ... | 4·00 |
| Silicon ... ... ... ... | 0·15 |
| Manganese ... ... ... ... | 0·18 |
| Sulphur ... ... ... ... | 0·010 |
| Phosphorus ... ... ... ... | 0·012 |

Briquettes.

| | |
|---|---|
| Iron ... ... ... ... ... | 59·0 |
| Sulphur ... ... ... ... | 0·010 |
| Phosphorus ... ... ... ... | 0·096 |
| Silica ... ... ... ... ... | 11·00 |
| Lime (CaO) ... ... ... ... | 2·50 |
| Alumina ... ... ... ... | 0·50 |

Steel Ingots.

| | |
|---|---|
| Carbon ... ... ... | 0·40 to 2·00 |
| Silicon ... ... ... ... | 0·12 |
| Manganese ... ... ... ... | 0·34 |
| Sulphur ... ... ... ... | 0·012 |
| Phosphorus ... ... ... ... | 0·014 |

The lining of this furnace during the year was magnesite, and when using briquettes the average life is represented by five weeks, but when working charges without briquettes the average life of the lining is seven weeks.

**Tempering and Cutting Tests of High Speed Steels.**—Dr. H. C. H. Carpenter records a series of experiments designed to ascertain whether the softening temperature of high speed steels can be raised above 700° C. Small specimens, about ¼ in. thick, were hardened by air blast quenching from a temperature of 1200° C. The structures of these quenched pieces generally consisted of white polyhedra, and the progress of tempering was followed by treating these hardened pieces at different temperatures and examining the resulting structural change. Taking one alloy steel as typical of the series, it is shown that no tempering occurs below 550° C. At 600° C. the white polyhedra disappear, and the structure consists of a fairly uniformly coloured, ill-defined granular mass from which all evidence of polyhedra is absent. At 650° C. small white crystals appear, but they do not obtain their proper proportion corresponding to fully tempered material until after treatment at 700° C. Further experiments were conducted with a view to examining the influence of initial quenching temperature on the temperature at which tempering becomes structurally evident. The results have shown that so far as tempering under purely thermal tests is concerned, provided the steel is quenched at the temperature at which, with ordinary rates of cooling, the splitting and lowering of the critical ranges is brought about, nothing is gained by exceeding this temperature.

**Comparison of American and Foreign Rail Specifications with a proposed Standard Specification to cover American Rails for Export.**—This memoir, by Mr. A. Ladd Colby, covers much ground, and, incidentally, much paper, but the comparison of rail specifications is most conscientious, and many unreasonable requirements are brought to light. Probably the most interesting part of the paper lies in the proposed standard specification to govern the manufacture in American mills of steel rails for export. The more salient parts of this specification are as follows:—

**Process of Manufacture.**—(*a*) The steel shall be of the best quality and made by the "Bessemer" or "Siemens-Martin" process. (*b*) The materials used and the entire process of manufacture and testing shall be in strict accordance with the best standard current practice, and special care shall be taken to conform to the following instructions. (*c*) No cracked or badly patched moulds shall be used, and the ingots shall be kept in a vertical position in the pit heating furnaces until ready to be rolled, or until the metal in the interior has had time to solidify. (*d*) No "bled" ingots shall be used, and no ingots from "chilled" heats rolled into first quality rails. A "bled" ingot is one from the centre of which liquid steel has escaped. A "chilled" heat is one which, because of the cooling of the steel, has to be either pricked or poured over the lip of the ladle. (*e*) Sufficient material shall be discarded or "cropped" from the top of all ingots to insure sound rails. (*f*) Under no circumstances shall an ingot or rail bloom be heated so high that the cinder on it runs when being drawn from the soaking pit or heating furnace. The ingots or blooms must be evenly heated throughout their length, drawn at a uniform temperature, and a uniform finishing temperature also maintained.

**Chemical Composition.** — Rails of various weight per yard shall conform to the following limits of chemical composition :—

| | 50 to 60 lbs. | Over 60 to 70 lbs. | Over 70 to 80 lbs. | Over 80 to 90 lbs. | Over 90 to 100 lbs. |
|---|---|---|---|---|---|
| Carbon ... ... ... ... ... | 0·30 to 0·40 | 0·35 to 0·45 | 0·35 to 0·45 | 0·40 to 0·50 | 0·40 to 0·50 |
| Manganese ... ... ... ... | 0·75 to 0·95 not over | 0·75 to 0·95 not over | 0·75 to 0·95 not over | 0·80 to 1·00 not over | 0·80 to 1·00 not over |
| Silicon ... ... ... ... ... | 0·10 | 0·10 | 0·10 | 0·10 | 0·10 |
| Phosphorus ... ... ... ... | 0·10 | 0·10 | 0·10 | 0·10 | 0·10 |
| Sulphur ... ... ... ... ... | 0·07 | 0·07 | 0·07 | 0·07 | 0·07 |

With regard to analyses, the manufacturer shall supply the representative of the purchaser, before the rails rolled on each turn are ready for shipment, with determinations of carbon and manganese on each heat of steel ; determinations of phosphorus on six heats every twelve hours, and determinations of silicon and sulphur on a sample representing each 12 hours rolling ; all said analyses to be made on a test ingot cast when teeming each heat.

**Impact Test.**—From either end of a rail, from every other heat of steel shall be cut at the hot saws, a piece from 4 to 6 ft. long, which shall be distinctly stamped with the heat number and set on skids to cool. When cool it shall be placed head upwards, on the supports of a standard American rail drop testing machine, and the various sections must withstand, without fracture, one blow of a 200 lb. tup from the height specified in the following table :—

Falling Weight Test.

| Weight of Rail. | Height of Drop. | Range in Carbon. |
|---|---|---|
| lbs. per yard. | feet. | per cent. |
| 50 up to and including 60 | 16 | 0·30 to 0·40 |
| More than— | | |
| 60 up to and including 70 | 17 | 0·35 to 0·45 |
| 70 ,, ,, ,, 80 | 18 | 0·35 to 0·45 |
| 80 ,, ,, ,, 90 | 19 | 0·40 to 0·50 |
| 90 ,, ,, ,, 100 | 20 | 0·40 to 0·50 |

The foregoing specification is essentially reasonable as far as the manufacturer is concerned, but it is a question whether British engineers would accept a phosphorus limit of 0·10 per cent.

**The Development of the Roe Puddling Process.**—Mr. Roe commences with a description of the ordinary puddling process, giving also an account of the mechanical aids which have at various times been applied to the process. Following this is a description of the author's efforts to produce large masses of puddled and squeezed iron which could be rolled direct into finished products without piling. This has been attained in stages starting from the preliminary idea that given an inclined trough, lined with iron oxide and heated, molten metal and cinder poured in at the top should result in a crudely-shaped ball by the time the metal reached the bottom. Although attractive, the proposition was impracticable in that the length of trough required would be about 2,000 ft., with an elevation of 600 ft. at one end ; further the cinder would almost always separate from the iron and lead in the race for the bottom. Following this line, it became evident that a trough of considerable length, down which the bath could flow first in one direction and then in the other, would possess all the advantages of the long-fixed trough. Together with the additional one of sudden arrest at each end, by which the bath would be forced through itself and a more intimate mixture obtained. An apparatus to realise these conditions was constructed, and many practical difficulties met, but, notwithstanding, the element of success had been reached. Finally, a furnace, moving through an arc of 140 degs., was constructed and arranged to be heated by means of oil fuel. Direct or cupola metal may be poured into the furnace, together with a certain amount of cinders, and oxidising materials are added by means of a charging spoon. The temperature of the flame is regulated as in the ordinary puddling process, and the furnace rocked during the whole of the operation. Ultimately a ball of puddled iron is formed, which is ejected into a hydraulic squeezing machine. This gives only a brief notion of the many phases through which the author has travelled, but his process is certainly worth study, and the idea of mechanically rocking fluid iron and cinder is good, and is a near approach to the conditions obtaining in the old puddling process.

**Effect of Low Temperature on the Recovery of Steel from Overstrain.**—Professor McCaustland records a series of experiments conducted under his supervision, with the object of ascertaining the behaviour

of steel after overstrain. The following table gives a summary of the tests :—

Table I.—Summary of Tests.

| No. | Kind. | Elastic Limit. | Stretch in 8 in. | Hours of Freezing Temperature. | Time of Recovery. | | Remarks. |
|---|---|---|---|---|---|---|---|
| | | | | | Moderate Temperature. | After Steam Bath. | |
| | | lb. sq. in. | in. | | hours. | hours. | |
| 1 | Soft | 27 500 | 0·0339 | None | 68 | | |
| 2 | ,, | 28,000 | 0·0366 | ,, | 69 | | |
| 3 | Mild | 32,000 | 0·0632 | ,, | 434 | — | Increased time of recovery due to greater stretch. |
| 4 | ,, | 32,000 | 0·0372 | ,, | 359 | | |
| 5 | Soft | 28 000 | 0·0517 | ,, | — | 25 | |
| 6 | ,, | 28 000 | 0·0512 | ,, | — | 26 | |
| 7 | Mild | 30,000 | 0·0129 | ,, | — | 24 | |
| 8 | ,, | 30,000 | 0·0147 | ,, | — | 119 | Increased time of recovery possibly due to higher cyclical loading. |
| 9 | Soft | 27,000 | 0·0244 | 2,112 | 142 | | |
| 10 | ,, | 27,500 | 0·0462 | 4,727 | 120 | | |
| 11 | Mild | 30,000 | 0·0206 | 2,707 | — | 93 | |
| 12 | Soft | 28,500 | 0·0468 | 2,111 | — | 24 | |

The table shows clearly that all the tests, of which specimens 1 to 9 are types, exhibit results in harmony with those obtained by other workers. The author is not aware of any tests which take into account the variation in the carbon contents of the steel, as affecting the time of recovery from overstrain; but it appears from these experiments that recovery is more gradual as the carbon increases. Specimens, numbers 5 and 6, of soft steel, show in a marked degree the accelerating effect of high temperature on the time of recovery. Since only two tests, numbers 7 and 8, were made on the mild steel, and since these show widely varying results as to time of recovery after the application of heat it can be concluded only that high temperatures hasten recovery to a degree which remains uncertain without further tests. As to these particular pieces, it may be possible that the difference in time of recovery is due, to some extent at least, to the higher cyclical loading to which No. 8 was subjected. Taking the experiments as a whole, the evidence appears conclusive that the effect of continued low temperature on a piece of steel which has been stretched slightly beyond the elastic limit is to arrest completely the recovery of its elastic properties. That is, if the permanent elongation has not exceeded, say, 1 per cent., no recovery of elastic properties will take place while the specimen is kept at a temperature at or below 32° F.

**Internal Stresses in Iron and Steel.**—Mr. H. D. Hibbard describes internal strains in iron and steel as the result of stresses within the mass of the piece, some parts pulling and others pushing in resistance to them; or, in other words, some parts are in tension and some in compression, each part striving to relieve itself from strain, and make the piece assume a form in which all parts are at rest. Subdivision, so that each part could relieve its strain by motion, relative to the other parts, would, if carried far enough, practically obliterate strain. For the purpose of his paper, the author divides internal strains into two classes (1) those caused by an irregular rate of change in temperature and (2) those caused by cold working or permanent change of form by mechanical means at atmospheric temperatures. The first class is the most important, and it is stated that the amount of change in temperature does not affect the strains produced, but that the rate determines all. Thus the strains due to irregular cooling are apparently between part and part, whilst those due to cold working may be considered as between molecule and molecule, because of the disarrangement of molecular formation. Strains due to the rate of heating or cooling may be regarded as arising during the cause which produces them, that is, temporary strains or those remaining after their causes have ceased to act, that is, permanent strains. Thus if an ingot of hard steel is placed in a red-hot furnace and is so ruptured internally by the quicker expansion of the exterior that it separates into pieces when forged or rolled, its ruin is the result of strains occurring while the cause, rapid heating, was in operation. If a cold boiler plate of soft steel cracks suddenly, it is because of strains existing after their cause had ceased its action. These are, of course, extreme cases in which the piece is ruptured by the intensity of the strains. Strictly speaking, permanent strains are but relatively permanent, since they decrease when the piece is again heated, or through seasoning or annealing action of time. The intensity of the strains considered depends on the following determining factors:—(1) The rate of change of temperature; (2) the shape of the piece; (3) the volume of the piece; (4) the elastic limit of the metal; (5) the ductility of the metal; (6) the coefficient of expansion of the metal. These

factors are examined in detail, and some interesting conclusions are given, of which we note chiefly No. 6. The coefficient of expansion, strictly speaking, wholly determines the intensity of the strains arising from irregular rates in change of temperature, for if it became zero such strains would not occur. The greater the rate of expansion, the more intense become the strains arising from a given rate of change in temperature. Heating a piece of iron or steel to any degree below the temperature at which it softens will increase the strains within it in proportion to the rate of heating. Therefore heating to relieve dangerous strain, which is often resorted to, must be slowly done, so that the interior is heated nearly as fast as the exterior, or the extra strain due to the more rapid expansion of the exterior parts may cause the rupture, it is the purpose of the heating to avoid.

Turning to internal strains caused by cold working, the author, whilst omitting a purely theoretical consideration, shows that they are the result of a molecular displacement. The phenomena occurring with these strains include higher tensile strength, higher elastic limit, greater hardness, less ductility, and lower specific gravity. Perhaps it is not claiming too much to say that these modified properties are the direct results of the strains, as if the strains be destroyed by heating to redness, all the modifications disappear with them, and the properties of the metal are substantially those it possessed before the cold working was performed. The effect of seasoning or annealing by time on cold worked iron or steel is probably not known, but is very likely an appreciable amount which in the case of bridge wire, for example, may reach important proportions with the lapse of decades.

**Notes on the Gayley Dry-Air Blast Process.**—Refrigerated blast has on various occasions had its fair share of attention in these columns; however, as the topic is still to the fore, some reference must be made to Mr. C. A. Meissner's paper under this heading. By an examination of available data Mr. Meissner reaches a series of conclusions which may be condensed into the following:

Increased blast temperature cannot alone account for the decrease of 20 per cent. in coke consumption and an increase of 20 per cent. in the product. Modern blast furnaces, equipped with stoves for producing high temperatures of blast have undoubtedly achieved much gain in product and fuel economy, but not enough to equal the gains secured in these respects by drying the blast—gains, in fact, which can be adduced to those of such previous progress. Apart from theoretical gains realised by the desiccation of the blast, the author's study of the records of practice impresses him with the predominant importance of the uniform and regular running of the furnace thereby secured.

**Different Modes of Blast Refrigeration.**—Mr. J. E. Johnson deals with means for determining plant and operating cost of the blast refrigerating apparatus. Without entering into the details of the paper, its broad conclusions may be summed up as follows; (1) The substitution of the direct expansion for the brine circulation system leads to important economies in first cost, in power required, and in attendance not off-set by any necessary advantage on the side of the brine circulation system. (2) The regenerative system leads to important economies in first cost, only in a minor degree offset by the loss of advantage to the blowing engine. (3) The two-stage method of refrigeration leads to important economies in first cost, in power requirements, and in absence of trouble with ice on the coils of the first stage not off-set by a disadvantage worth considering. (4) By a combination of these methods, as compared with the brine circulation, single stage, non-regenerative system, it is possible to dry the blast with less than half the first cost for plant, with much less attendance, and with one-third the power. (5) From a commercial point of view there is no gain in refrigerating the air to too low a temperature, 32° being probably as low as it pays to go in summer and 22° in winter.

**The Nodulising and Desulphurisation of Fine Iron Ores.**—Mr. A. Ladd Colby commences with a description of various plants at work for nodulising fine iron bearing material. Nodules so made from pyrites cinder, concentrated magnetite and flue dust have been used at six different blast furnace plants with entire success. Briefly, the treatment consists in purifying finely-divided metalliferous materials and forming them into nodules or lumps, by adding to the materials a binder, preferably reducing in character, adhesive at low temperatures and volatile at fairly moderate temperatures, which binder has an affinity for and is capable of forming volatile compounds with impurities such as sulphur and arsenic. In practice, any adhesive hydrocarbon, or carbohydrate compound such as tar, pitch, asphalt, petroleum residuums, dextrine molasses, glucose, &c., may be used provided it can be made liquid or plastic at comparatively low temperatures, and can be readily and cheaply obtained. The adhesive binder drops or is sprayed into the stream of fine material as it enters the upper end of an inclined rotary kiln; the material is at once cohered into masses, which by the rotary action break up into nodules or lumps. One per cent. or less of an adhesive binder such as tar is sufficient. When the lumps reach a zone of higher temperature the tar combines with the sulphur, and both are volatilised. When the nodules approach the lowest and hottest end of the kiln incipient fusion takes place, so that the product is a nodule permanently cohered without the presence of any extraneous binder.

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